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SEARCH ROOM

Feb. 2, 1960 H. K. BRADFORD 2,923,882

SIGNALLING APPARATUS

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FIG. 1.

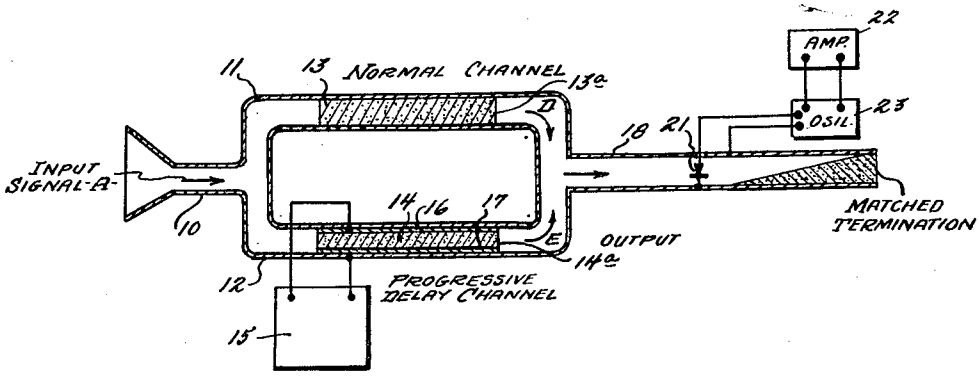


FIG. 9.

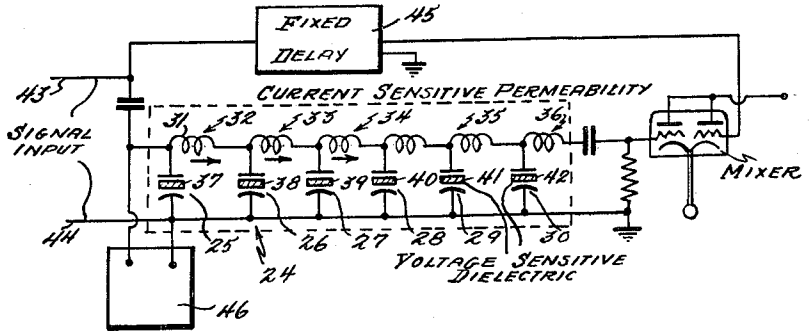


FIG. 5.

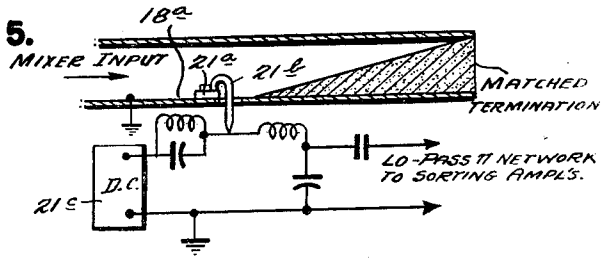
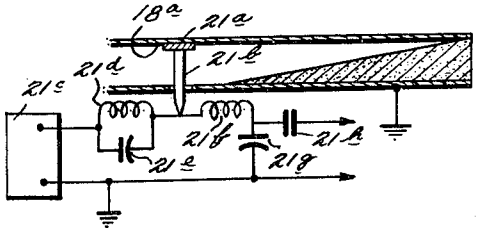


FIG. 6.



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FIG. 3.

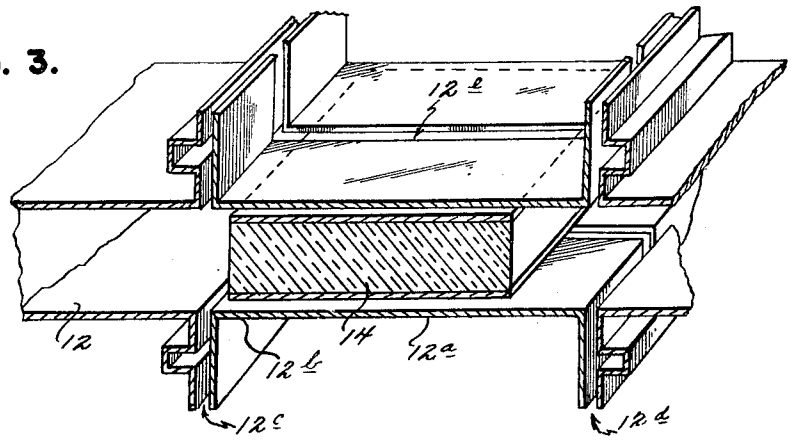


FIG. 2.

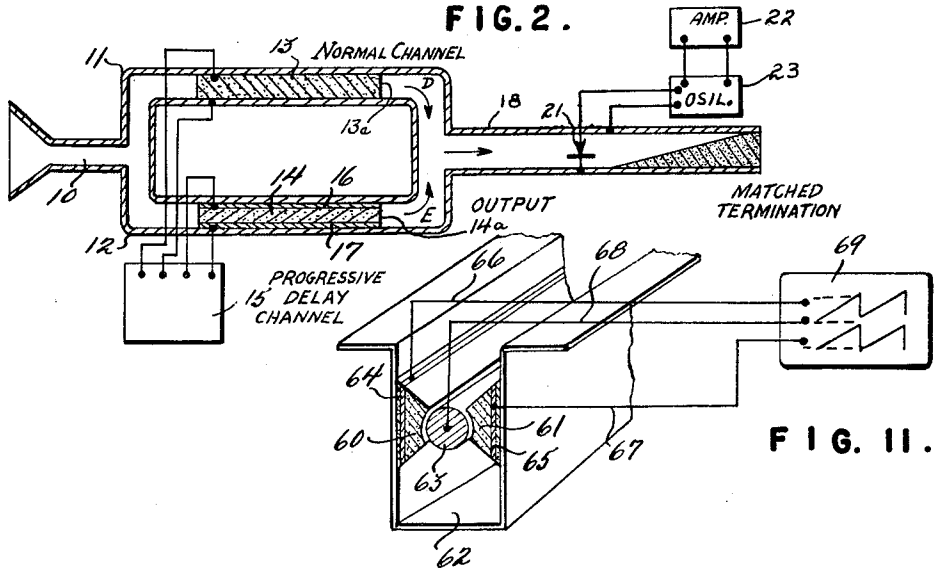


FIG. 11.

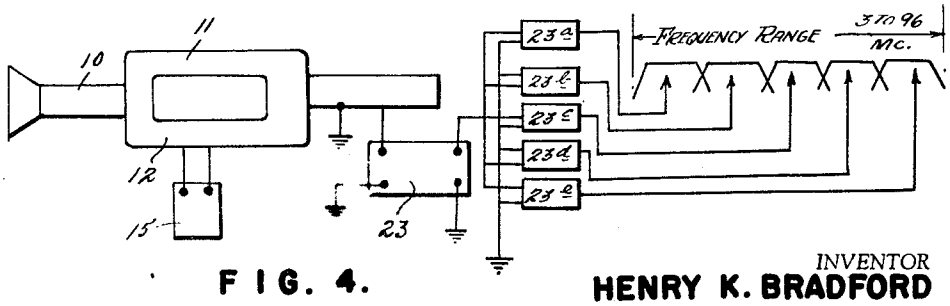


FIG. 4.

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FIG. 7.

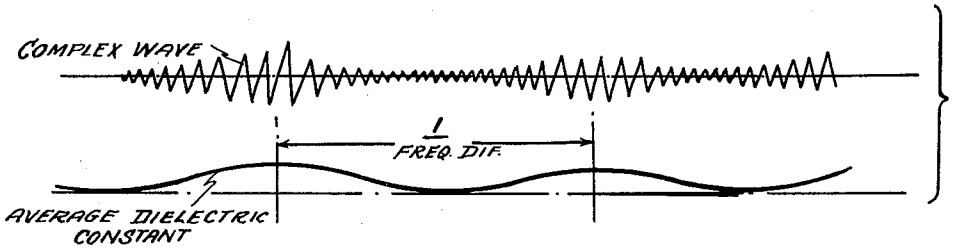
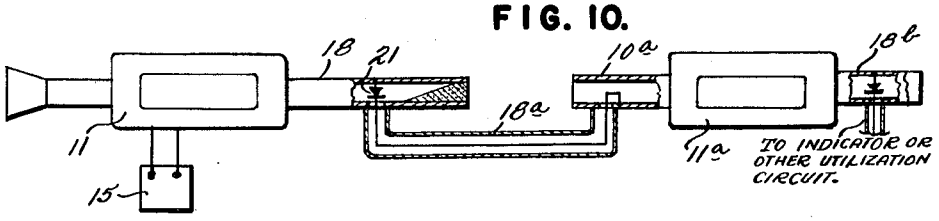


FIG. 10.



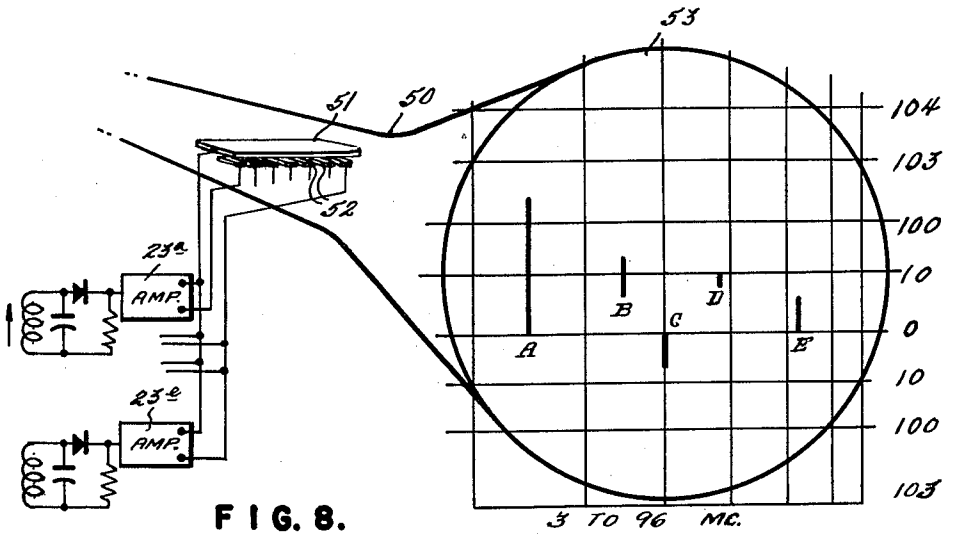


FIG. 8.

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United States Patent Office 2,923,882 Patented Feb. 2, 1960

2,923,882

SIGNALLING APPARATUS

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Application November 14, 1955, Serial No. 546,594

12 Claims. (Cl. 324—77)

This invention relates to signal transmission and reception in general. More particularly, this invention relates to signal transmission and reception over a wide portion of the spectrum by the use of electrical frequency dividers.

An object of this invention is to provide an improved frequency divider and wave analyzer.

Another object of this invention is to provide a signal receiver for signals on the order of 70 kmc. to 120 kmc. in which frequency division is accomplished without the conventional beat frequency oscillation generator.

Still another object of this invention is to provide an improved frequency divider and wave analyzer that may be employed with high frequencies as well as with audio frequencies.

A further object of this invention is to provide an improved frequency divider and wave analyzer in which the frequency division may be continuously varied over a predetermined range, which may include a very large section of the frequency spectrum limited only by the signal frequency range carried by the waveguide or other signal carrier.

Still another object of this invention is to provide an improved frequency divider and wave analyzer adapted to be employed for receiving signals in the SHF band and in which the signals are divided by a factor in the neighborhood of 1,000.

Another object of this invention is to provide an improved frequency divider and wave analyzer employing a signal delay channel that is provided with a dielectric in which the dielectric constant may be varied so as to control the delay of the signal passing through this channel.

Another object of this invention is to provide an improved delay line including a voltage sensitive dielectric for delaying the signal passing through the delay line in accordance with the magnitude of the voltage that is applied to the dielectric.

Another object of this invention is to provide an improved signal receiving apparatus in which the signal is divided into a normal signal and a delayed signal, a delayed signal being passed through a voltage sensitive dielectric in order to variably delay this signal, the normal signal and delayed signal being thereafter mixed to beat or heterodyne with one another to form a beat frequency which may be detected or demodulated and the signal components thereby received with or without amplification.

Another object of this invention is to provide a signal wave analyzer for use with signals having frequencies on the order of 10 kmc. in which no beat frequency oscillator is employed.

Other and further objects of this invention will be apparent to those skilled in the art to which it relates from the following specification and claims.

In dealing with electronic techniques in many branches of use and investigation above the UHF spectrum it is found that the tunable band ranges become more limited.

Both mechanical and electrical tuning methods decrease in percentage band coverage as frequency is increased and ordinary refinement of these techniques using conventional methods has not greatly extended this coverage. The degree of this limitation is at once realized from a look at the tuning characteristics of klystrons, BWO tubes, and retarded field oscillators.

Above 10 kmc., a tuning range of 5 percent is considered exceptional when using klystrons. Retarded field oscillators have been designed for an octave coverage but these have not found their way into practice. Moreover, the compromises which must be made in the application of crystal-video techniques are so great that advantages of band width are all but lost. The difficulty in this application centers around low level mixers.

In this invention this problem was approached from an entirely new direction in a desire to produce a frequency divider and wave analyzer having the greatest possible band coverage a single simple unit.

In accordance with this invention there is provided an improved frequency divider and wave analyzer which has many applications and is particularly adapted for reception of signals in the SHF band although it may, of course, be employed in any part of the entire frequency spectrum. Briefly, this system consists of a circuit which splits the signal wave or input energy into two components. This circuit may consist of a wave guide, a coaxial line, a paired line or other signal channel. One of the split signals is passed through a normal circuit or channel whereas the other of the split signals is passed through a circuit or channel that is fitted with a voltage sensitive dielectric in which the dielectric constant will vary with the application of a D.C. voltage to the electrodes thereof. Thus, the signal passing through the dielectric can be delayed in predetermined amounts depending upon the voltage applied to the dielectric.

The signal component passing through the normal channel and the signal component passing through the delay channel are brought together at the outputs of these channels and are mixed to form a beat frequency or heterodyne signal. At the same time the signal may be detected or if the signal is small in amplitude an auxiliary oscillator may be used so that the crystal devices used for detection will function properly. The heterodyne signal may then be amplified by suitable amplifiers. Where this invention is employed with very high frequencies, such as those encountered in the SHF band, a number of amplifiers adjusted for amplifying adjacent and overlapping bands may be employed so that the entire band width of the heterodyne signals will be properly amplified. These and other details of this invention will be set forth in the following specification and the drawing, in which briefly:

Fig. 1 is a schematic drawing of an embodiment of this invention;

Fig. 2 is a modification of this invention;

Fig. 3 is a detail sectional view of one form of progress signal delay channel adapted to be employed in accordance with this invention;

Fig. 4 is a schematic drawing of the apparatus shown in Fig. 1 coupled to a group of amplifiers;

Figs. 5 and 6 are views showing modified forms of mixers adapted to be employed in accordance with this invention;

Fig. 7 is a view showing signal waveform and average dielectric constant graph used to explain the operation of the mixers shown in Figs. 5 and 6;

Fig. 8 is a view of a visual indicator adapted to be employed in accordance with this invention;

Fig. 9 is a view showing a modified form of this invention adapted for use with lower frequency signals of

audio or super audio ranges or signals up to ten megacycles;

Fig. 10 is a view of a modification showing two units of the type shown in Fig. 1 connected in cascade; and

Fig. 11 is a view of a modified form of this invention applied to open sided signal carriers such as are used in signal measurements.

Referring to the drawing in detail, there is shown in Fig. 1 an embodiment of this invention in which a signal channel **10**, such as a waveguide, is divided into two similar channels **11** and **12** so that equal components of the signal are introduced into each. Channel **11** may be referred to as the normal channel and channel **12** as the progressive delay channel.

Similar dielectrics **13** and **14** are placed into the channels **11** and **12**, respectively, and these dielectrics are selected to introduce considerable delay into the signal components with a minimum of loss. The dielectric **14** must have a voltage sensitive characteristic such that its dielectric constant may be varied as a function of voltage applied thereto by a satisfactory amount. A suitable dielectric for this purpose is barium strontium titanate.

A saw-tooth voltage or other voltage source **15** is connected to the electrodes **16** and **17** that are applied to the dielectric **14**. These electrodes are insulated from the waveguide **12** so that the voltage supplied by the source **15** is not short circuited through the waveguide. Other ways of accomplishing this will be described hereinafter.

The rate of voltage change of the source **15**, that is, its differential or rate in volts per second is made to match the voltage dielectric function of the voltage sensitive dielectric **14**. This is done to produce a signal component E having a linear frequency shift, emerging from the end **14***a* of the dielectric **14**. This frequency shift will differ from that of the signal component D emerging at the end **13***a* of the dielectric **13** by a fixed amount for the duration of the changing voltage function.

If the dielectric **14** is one having a dielectric constant of 100 with a loss factor of .0003, it has a voltage sensitivity of −60 percent per 500 volts. Let us assume that for a change of dielectric constant of 100 percent, 200 volts is required. As the propagation velocity of the signal through the dielectric **14** is proportional to the square root of the dielectric constant, it follows that the velocity of propagation will change approximately 5 percent with a 200 volt change.

For the purpose of describing the operation of this invention, assume that a 10 kmc. signal is progressing through the waveguide at the rate of 10,000 wavefronts per microsecond. A substance **14** placed in the waveguide having a delay of $\frac{1}{10}$ microsecond will therefor contain 1,000 wavefronts. If this substance has a dielectric constant K of 100 it would have to be 10 free-space wavelengths long to contain 1,000 wavefronts at one time.

If the velocity of propagation is decreased 5 percent per microsecond, the dielectric must contain 1050 wavefronts. It accumulated 50 additional wavefronts each microsecond and the signal frequency is thus reduced 50 mc., over a one microsecond interval. However, the dielectric is acting on the signal only during $\frac{1}{10}$ microsecond in which case the frequency difference is only 5 mc. This requires the voltage slope to be 200 volts per microsecond which is a value that may be difficult to attain. At a slope of 200 volts per millisecond the frequency difference will be 5 kc., which is not very useful in this signal frequency range. However, the loss involved is negligible.

In order to overcome the above difficulties, a dielectric **14** with a constant K equal to 1000 was selected. By making it occupy a free space wavelength of 10 wavelengths, it will contain 10,000 wavefronts and will produce a delay of one microsecond. Acting on 10 times the field length and having 10 times the voltage sensitivity, the frequency reduction factor in the dielectric **14** will be incresed 100 fold. A beat frequency of 0.5 mc., will thus be formed. Further by using a dielectric having a constant K=6,000, we multiply the factor by 36 or the square of 6 because the voltage sensitivity and the physical volume of material acted upon are both increased by a factor of 6. This brings the beat frequency up to 18 mc. At 18 mc., we have achieved a division ratio of 10 kmc./18 mc.=557.

The voltage from the source **15** may be impressed across both of the dielectrics **13** and **14** but in opposite phase so that the rate of signal delay in one dielectric is increasing while the rate in the other is decreasing. Such an arrangement is shown in Fig. 2 in which the dielectric **13** is provided with electrodes **19** and **20** that are connected to the voltage source **15**. The beat frequency will in this modification be doubled to 36 mc., from the 18 mc. value obtained when the voltage is applied only to the dielectric **14**.

The frequency division ratio is controlled directly by the slope of the saw-tooth or dielectric function voltage. This voltage-dielectric function may be made linear or non-linear as desired. The signal components emerging from the dielectrics **13** and **14** are recombined in the waveguide **18** to which the branches **11** and **12** are joined and thereafter the combined signal components are simultaneously mixed by a conventional crystal **21** or by a new type of mixer to be described.

The dielectric **14** may be mounted in a waveguide section **12***a* as shown in Fig. 3. The input end **12***b* of this section is coupled through the gap type coupler **12***c* to the waveguide **12** which is one of the branches shown in Fig. 1. The output of the section **12***a* is coupled through a similar gap type coupler **12***d* to provide the signal E.

In the section **12***a* there is provided a gap **12***e* which extends from the input end to the output end both on the top and the bottom of the section. This gap divides the section into two parts and these parts are connected across the output of the saw-tooth oscillator **15** so that the saw-tooth voltage is applied across the dielectric from one side to the other. It is, of course, obvious that a gap **12***e* may be provided to each of the sides of the section **12***a* instead of the top and bottom as shown, if it is desired to apply the saw-tooth across the dielectric from the top to the bottom and vice versa.

In order for the crystal **21** to operate in the most favorable portion of its operating characteristic for high mixing efficiency, an auxiliary oscillator **23** may be used to drive the crystal. The frequency of the auxiliary oscillator is chosen well out of the band-pass of the I.F. or sorting amplifier **22** and the emerging signal D plus or minus E is amplified to the extent that may be required. The relation D plus or minus E bears a fixed ratio to the input signal A, which ratio is determined by the slope of the saw-tooth voltage function as previously described.

The oscillator **23** may employ a klystron type tube in a Shepherd-Pierce circuit and the I.F. output from this beat frequency oscillator may be connected to the inputs of a series of I.F. amplifiers **23***a*, **23***b*, **23***c*, **23***d* and **23***e*, each covering a different frequency range, as shown in Fig. 4. Amplifier **23***a* is adjusted to amplify a band from 3 to 6 mc., amplifier **23***b* a band 6 to 12 mc., amplifier **23***c* a band 12 to 24 mc., amplifier **23***d* a band 24 to 48 mc., and amplifier **23***e* a band 48 to 96 mc., whereby the whole I.F frequency range 3 to 96 mc., of the signal derived from the beat frequency oscillator may be amplified.

In Figs. 5 and 6 there are illustrated low level types of mixers that employ barium titanate elements **21***a* instead of a crystal detector such as the detector **21** shown in Fig. 1. One side of the element **21***a* is cemented to a wall of the waveguide **18***a* and a connection **21***b* is cemented to the other side of the dielectric element **21***a*.

The member **21***b* may be in the form of an inductive pick-up loop as shown in Fig. 5 or it may be in the

form of a post probe as shown in Fig. 6. In this way the signal current from both the D and E signals is produced in the device shown in Fig. 1 and supplied to the mixers shown in Figs. 5 and 6 and these are impressed upon the dielectric material **21***a* in the form of a complex wave such as is illustrated in Fig. 7. This complex wave appears as a high frequency wave modulated in amplitude by the beat frequency derived from the signals D and E. This beat frequency may, of course, be the difference between the frequencies of the signals D and E. The amplitude of the beat frequency will change the average dielectric constant of the dielectric element **21***a* as schematically represented in the lower curve shown in Fig. 7. Hence the capacitance of the element **21***a* is changed.

A small D.C. voltage is supplied from the source **21***c* and this voltage is impressed across the dielectric element **21***a* through a suitable choke coil **21***d* which is shunted by capacitor **21***e*. The impedance of this tuned circuit is as high as possible at the inter-modulation frequency.

The capacitor, including the dielectric **21***a*, will change its average voltage at the inter-modulation frequency in an attempt to charge and discharge as a consequence of its changing capacitance. This capacitance includes the capacitance of the low pass network including the capacitors **21***g* and **21***h*. This network may be connected to one or more sorting amplifiers such as the amplifiers **23***a*—**23***e* shown in Fig. 4. Thus, the voltage change at inter-modulation frequencies is amplified and supplied to other signal circuits as may be desired and one such circuit comprises a visual indicator.

A visual indicator circuit such as may be employed in connection with the sorting amplifying circuit shown in Fig. 4, is shown in Fig. 8. This circuit is provided with a cathode ray tube **50** having a conventional electron gun which is arranged to produce a flat fan-shaped electron beam. This tube is provided with a flat deflector electrode **51** that is connected to one side of the outputs of all of the amplifiers **23***a*—**23***e*. The flat fan-shaped beam is projected below the flat electrode **51** and above the narrow strip electrodes **52** that are positioned below the flat electrode **51** and spaced therefrom. With no signal applied to the electrodes **51** and **52** from the outputs of the amplifiers, the flat fan-shaped beam impinging upon the fluorescent screen **53** of the tube **50** will produce a horizontal line along the zero ordinate of the scale applied to the front of the screen of the tube. The abscissa of this chart may be calibrated in terms of frequency corresponding to the frequencies covered by the amplifiers **23***a*—**23***e*.

The amplifiers **23***a*—**23***e* in this case may be wide band logarithmic video amplifiers connected so that all amplitude modulated signals provide a deflection upward from the zero line as shown by the indications A, B, D and E. Discriminator outputs resulting from a frequency modulated signal are polarized to deflect a beam downward as shown by the indication C.

The output of the sorting amplifier is fitted with a number of band pass filters overlapping to form a continuous spectrum but each filter has its own detector, amplifier (video) and deflection plate. A wide band logarithmic video amplifier allows an upward deflection of all A.-M. signals such as the 800 μv. signal shown at A (4 kmc., modulated C.W.), the 60 μv., 8 kmc. signal shown at B, C.W. 10 μv. signal shown at C, and the 7 μv., 60 kmc. pulse shown at E. Discriminator outputs are polarized to deflect downward such as shown at C to distinguish them from A.-M. signals. Here an 8 μv., 12 kmc. F.-M. pulse is indicated.

Frequency is arranged to be dispersed logarithmically on the horizontal of the screen by the filter design, while magnitude is indicated vertically on a logarithmical response scale. Pulses will form a vertical line while C.-W. will form an elevated point, the height of which is a measure of signal magnitude.

In Fig. 9 there is shown a modified form of this invention in which voltage sensitive capacitors **25**, **26**, **27**, **28**, **29** and **30** are connected into a lumped delay line **24** that also includes the inductance coils **31**, **32**, **33**, **34**, **35** and **36**. The voltage sensitive capacitors **25**, **26**, **27**, **28**, **29** and **30** are provided with dielectrics **37**, **38**, **39**, **40**, **41** and **42** respectively, and these dielectrics are of the barium strontium titanate type having characteristics similar to the dielectric **14** shown in Fig. 1 and described in connection therewith.

The inductance coils **31** to **36** inclusive, are of the type having current sensitive permeability and for this purpose these coils may be provided with ferromagnetic ferrite cores having the desired electromagnetic properties.

This modification of this invention is designed for use with lower frequency signals than the embodiment shown in Fig. 1 and these lower frequency signals extending over a wide frequency band are applied to the input lines **43** and **44**. Part of the signal is fed to the variable delay channel including inductance coils **31**—**36** and capacitors **25**—**30** and the other part of the signal is fed to the fixed delay line **45**. The oscillation generator **46** is of the type adapted to generate a voltage having saw-tooth waveform and this generator is connected across the delay line capacitors **25**—**30** so as to vary the voltage sensitive dielectric thereof as previously described in connection with Fig. 1 Suitable chokes or couplers are employed for preventing the signal from going into the generator **46**.

It is obvious that the delay line **45** may be constructed the same as the variable delay line **24**. In that case both delay lines **24** and **45** are variable, one increasing signal delay while simultaneously the other is decreasing, and in that modification the generator **46** is also connected to the delay line **45** for the purpose of applying a varying voltage to the voltage sensitive dielectric elements thereof.

Several of the units such as shown in Fig. 1 may be employed in cascade as illustrated in Fig. 10 wherein the output of the mixer **21** of the first unit **11** is coupled through the coaxial line **18***a* to the input of the second stage **11***a*. This second stage is similar to the first stage in that it also provides two signal paths, one of which may be referred to as a normal signal channel and the other of which may be referred to as a channel with periodically progressively delayed signal characteristics. It is, of course, obvious that both channels of stages **11** and **11***a* shown in Fig. 10 may be of the type shown in Fig. 2 wherein both signal paths in each stage have periodically progressively delayed signal characteristics. The result of this modification is a greatly increased frequency division in the mixer circuit coupled to the output **18***b* of the second stage **11***a*. It is, of course, obvious that the output of the stage **11***a* may be coupled to the input of a stage such as is shown in Fig. 9 if desired.

A still further modified application of this invention is shown in Fig. 11 wherein sections of dielectric **60** and **61** are positioned in the open side type of SHF wave carrier **62** that is adapted for use in certain measurements. A conductor **63** is positioned in this carrier and access may be had to different points of this conductor through the open side of the carrier for the purpose of making measurements. Suitable electrodes **64** and **65** are provided to the dielectric elements **60** and **61** and these electrodes extend along the full length of the dielectric elements. These electrodes are insulated from the walls **60** and **61** of the carrier and they are also connected by conductors **66** and **67** respectively, to the saw-tooth oscillator **69**, the center conductor **68** of which is connected to the conductor **63** of the carrier so that voltages of the saw-tooth waveform shown are applied between these electrodes **64** and **65** with respect to the conductor **63**.

As a result the dielectric elements **60** and **61** both function to introduce progress signal delay into the carrier as the amplitude of the saw-tooth voltage increases.

This invention is susceptible of various modifications and applications in the communications field and it is therefore not desired to limit it to the embodiments described in the foregoing specification except insofar as they are defined by the following claims.

What I claim is as follows:

1. A wide band electrical frequency divider comprising a radio frequency signal channel, means for dividing said channel into a normal channel and a signal delay channel, said delay channel having electrically responsive means for introducing a time rate of change in the delay of transmission of the signal therethrough, means for mixing the output signals from said normal channel and from said delay channel to produce a signal of reduced frequency, the reduction in frequency being determined by the time rate of change of delay in said signal delay channel.

2. A wide band electrical frequency divider comprising a radio frequency signal channel, said channel being divided into a normal channel and a signal delay channel, said delay channel having electrically responsive means for progressively increasing the delay of transmission of the signal therethrough, means for mixing the output signals from said normal channel and from said delay channel to produce a signal of reduced frequency, the reduction in frequency being determined by the time rate of change of delay in said signal delay channel.

3. Signalling apparatus comprising a radio frequency signal channel, means for dividing said channel into a normal channel and a signal delay channel, a voltage sensitive dielectric in said delay channel for delaying the transmission of the signal therethrough, a source of variable voltage connected to said dielectric for introducing a time rate of change in the signal delay in said dielectric in accordance with said voltage, means for mixing the output signals from said normal channel and from said delay channel to produce a signal of reduced frequency, the reduction in frequency being determined by the time rate of change of delay in said signal delay channel.

4. Signalling apparatus as set forth in claim 3 further characterized in that said voltage sensitive dielectric comprises a dielectric of barium strontium titanate.

5. Signalling apparatus as set forth in claim 4 further characterized in that the source of variable voltage generates a sawtooth voltage wave.

6. Signalling apparatus as set forth in claim 5 further characterized in that the normal channel is also provided with a voltage sensitive dielectric, said last mentioned dielectric being connected to said voltage source so that the dielectric constant thereof varies inversely as the dielectric constant of said dielectric in said delay channel.

7. Signalling apparatus as set forth in claim 3 in which the delay channel comprises a series of lumped inductors and capacitors and in which the voltage sensitive dielectric forms the dielectric for said capacitors.

8. Signalling apparatus as set forth in claim 3 further comprising a plurality of amplifiers connected to said signal mixing means, each of said amplifiers being adapted to amplify a different frequency spectrum covered by the signalling apparatus and a visual indicator comprising a cathode ray tube having a plurality of beam deflecting means, different ones of said beam deflecting means being connected to the output of different ones of said amplifiers.

9. Signalling apparatus as set forth in claim 3 further characterized in that said signal mixing means comprises a voltage sensitive dielectric which is connected so that the dielectric constant thereof varies in accordance with the voltage of the output signal.

10. Signalling apparatus as set forth in claim 3 further characterized in that one of said channels is provided with a conductor positioned inside thereof and in which the voltage sensitive dielectric is positioned on the sides of said conductor.

11. Signalling apparatus as set forth in claim 10 further characterized in that said source of voltage is connected between said conductor and the channel associated therewith.

12. A wide band electrical frequency divider comprising a radio frequency signal channel, means for dividing said channel into a normal channel and a signal delay channel, a voltage sensitive dielectric in said delay channel for delaying the transmission of the signal therethrough, said dielectric having a length such that it contains several thousand signal wave fronts at a given instant, means for periodically varying the dielectric constant of said dielectric so that a progressively increasing delay in signal transmission is introduced therein from the time a signal wave front enters said dielectric until it leaves, and means for mixing the output signal from said normal channel with the output signal from said delay channel to produce a signal of reduced frequency, the reduction in frequency being determined by the time rate of change of delay in said signal delay channel.

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