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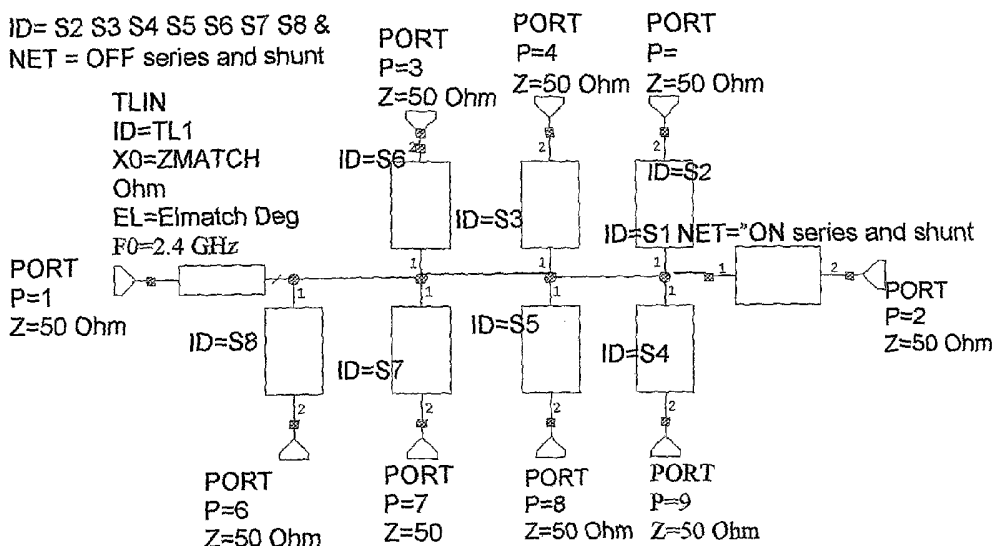
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(54) Title: RADIO FREQUENCY AND DATA SWITCH



Block Diagram of complete 8-Way Switch

(57) Abstract: A solid state Duplex RF switch, Capable of passing a RF Carrier (Modulated) from a single source to any one (by selection) of a number, theoretically unlimited, switched ports. The switched port is selected by a data link which is distinctly isolated from the RF path and is of the form of a command and telemetry link to a processing device which will run a program of events to select the desired Duplex RF Port. Once selected and whilst remaining so, the switched port appears Transparent to the RF Path. The command and telemetry aspect is always transparent to the operation of the RF Path. The switch operates over a wide bandwidth.

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Radio frequency and data switch.

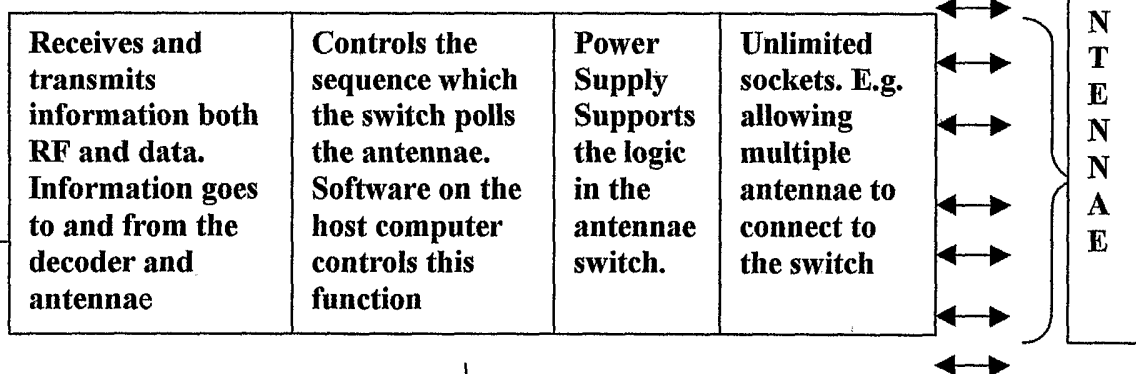
An intelligent switching device. This switch will be capable of taking data from a theoretically unlimited number of different locations and re-routing this data to a single decoder.

The switch will be able to route both Radio Frequency and data information.

Proposed Solid State Switch

Based on a standard integrated circuit which will provide duplex command and telemetry of the switch

To / from Decoder



Switch socket command and control port

Specification

- **Switch must be capable of interrogation and report back its current state (switch position and serviceability).**
- **The RF path shall be a duplex path via the switch.**
- **The RF path shall be capable of handling at least 25 W constant carrier.**

Design Criteria

There are many systems, which utilise RF services modulated with data to command, control and monitor remote systems. The switch will enable multiple remote systems of like design to be controlled and monitored by any a single source device and processor.

Unique

To our knowledge there is no constant carrier RF multi - switching device currently available. The nearest device found is a two position RF switch which inhibits the transmission path whilst switching. This device also has a delay is in-built immediately after switching for the system to settle.

We anticipate that the development of the switch will enable companies to supply full turnkey solutions to their customers. It is envisaged filing cabinets; shelves etc. will be designed with the antennae built in, possibly even the switch. With established locations antennas will be installed in existing shelves and drawers etc.

Software will be developed to make use of the flexibility the switch gives to design tracking systems, stock control etc.

Radio frequency Switch.

A solid state Duplex RF switch, Capable of passing a RF Carrier (Modulated) from a single source to any one (by selection) of a number, theoretically unlimited, switched ports.

The switched port is selected by a data link which is distinctly isolated from the RF path and is of the form of a command and telemetry link to a processing device which will run a program of events to select the desired Duplex RF Port.

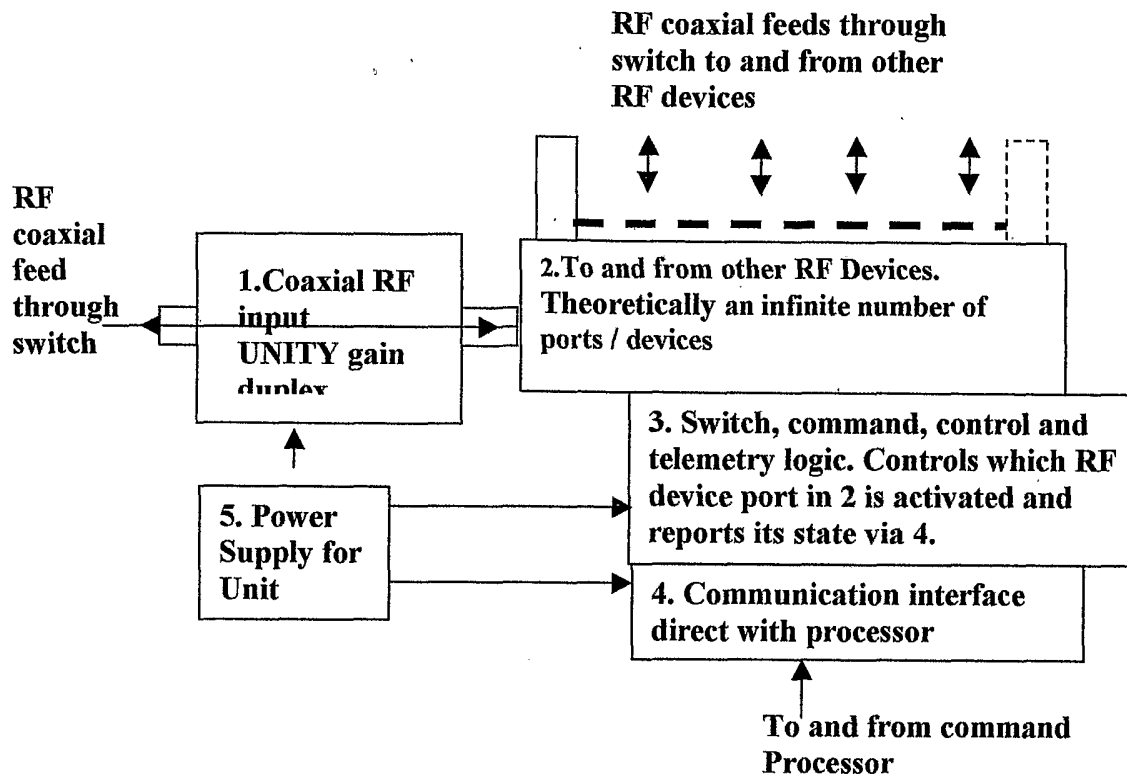
Once selected and whilst remaining so, the switched port appears Transparent to the RF Path.

The command and telemetry aspect is always transparent to the operation of the RF Path.

Proposed Solid State Switch

The command and telemetry aspect of the switch is based on solid state circuitry that is readily available and of standard functionality.

The unit therefore appears as two distinct functions, which are interactive, one dependant on the other but isolated from its function by design.



- 1. Coax RF input / output with a UNITY gain duplex amplifier - Communicating RF information to and from the selected port in 2. Power from 5 regulates the current fed to 1 powering the RF device.**
- 2. Multiple port input / output (theoretically infinite) connecting remote RF devices / sensors.**
- 3. Switch command, control and telemetry logic. Taking software instructions selecting port position in 2 to be activated from the processor via the communications chip 4. Powered from 5**
- 4. Input / output interface - Standard communications I/C's like RS232, USB, Fire Wire etc.**

5. Power Supply for Unit.

The RF path shall be a duplex path via the switch.

- **The RF path shall be capable of handling at least 25 W constant carrier.**

Design Criteria. There are many systems, which utilise RF services modulated with data to command, control and monitor remote systems. The switch will enable multiple remote systems of like design to be controlled and monitored by any a single source device and or processor

The communications is based on a standard integrated circuit, which will provide duplex command, control and telemetry of the switch

Switch socket command, control and telemetry port.

Specification

- **Switch is capable of interrogation and will report back its current state (switch position and serviceability).**

Unique

To our knowledge there is no constant carrier full duplex RF multiple switching device currently available. The nearest device found is a two position RF switch which inhibits the transmission path whilst switching.

Patent Proposal for a High Performance Dual Frequency Multi-Way Switch with High Reliability

The component described in this document is a novel representation of a high performance dual frequency multi-way switch with high reliability, which is suitable for practical implementation where it is desired to switch between a large number of output ports and maintain high isolation and good input and output match.

The switch is required to route an input RF or data signal to one of a number of outputs and operate over a narrow bandwidth at 13.96 MHz and 2.4 GHz. Such a requirement can, in principle, be met by having a number of series switching devices connected to a common feed point. While this approach is adequate for operation at 10s of MHz, the associated 'off' state capacitance of any practical switching device seriously degrades the input and output match and the isolation of the switch at 100s of MHz and above, e.g. 2.4 GHz. The approach to overcome this limitation at 2.4 GHz will be discussed in the following paragraphs.

Firstly, a transmission line technique to improve the input and output match at 2.4 GHz is used. This approach 'tunes out' the effect of the 'off' state capacitance by using an approximate $\lambda/2$ line between the common feed point and each individual switch circuit. The approximate $\lambda/2$ line transforms the switch impedance in the 'off' state to a high impedance at the common feed point approximating an open circuit. This reduces the impedance loading at this point from the

switches in the 'off' state and largely removes the adverse effect on the input and output match.

Secondly, a technique to ensure adequate isolation is implemented. The isolation between the input and outputs in the 'off' state is also largely determined by the 'off' state impedance of the switching device. This presents a limit on the isolation, which can be achieved when only series switching devices are used. Therefore, in order to ensure that an isolation of >25 dB can be achieved, a shunt device on each output is also used. Each shunt device is 'on' when each series device is 'off' and vice versa. This effectively grounds the input signal to the outputs set to the 'off' state. A circuit diagram for the 'on' and 'off' state of each switch device with the approximate $\lambda/2$ line is given in Figure 1 and Figure 2 respectively.

See figure 1 & 2 : ON and Off

The above approach to a dual frequency switch design has some bandwidth limitations. The transmission line properties of each $\lambda/2$ line means that it is only possible to achieve a good match over a limited bandwidth at 2.4 GHz. At 13.96 MHz, the effect of these transmission lines is to provide an approximate capacitive loading and degrade the input and output match by a small amount, which progressively degrades with the number of switch outputs.

Several different architectures were investigated for the realisation of a 64-way switch bearing in mind the above concept. The two most promising designs used a) one 8-way switch with each of the outputs

connected to an 8-way switch, i.e. nine 8-way switches in total, and b) one 4-way switch with each output connected to a 4-way switch and each of those outputs connected to additional 4-way switches, i.e. twenty one 4-way switches in total. Option a) has the advantage over b) of lower insertion loss and of using a smaller number of devices, but the disadvantage that the bandwidth at 2.4 GHz is lower. Since the bandwidth requirement is around 1 MHz or less, this was not seen as a limitation and the 8-way design was selected for the baseline design for the prototype.

See Figure 3: 8way switch

Two basic types of switching device were considered: a) electromechanical, e.g. miniature electromechanical and reed switches and b) solid state, e.g. PIN diodes and d) FET/HEMT type switches.

Both types of electromechanical switch offer excellent performance in terms of isolation and insertion loss. Many of the miniature types available today have superior RF performance that their solid state equivalent to well over 2.5 GHz. However, the switching speed is relatively slow, e.g. 10 ms for a miniature electromechanical switch compared with 0.04 us in a solid state switch and the number of guaranteed switching cycles before loss of performance is too low for this application, e.g. $\sim 10^6$ switching cycles, unless the switching rate is very low. In view of these limitations, a solid-state device is the only acceptable solution. PIN (p type-intrinsic-n type semiconductor) diodes are well established for switching and control purposes at RF

and provide the best performance of any solid-state device due to their high Q. However, recent advances in three terminal device technology in FETs (Field Effect Transistors) and HEMTs (High Electron Mobility Transistors) means that these devices are now available with performance approaching that of PIN diodes at frequencies up to 2 GHz. A further significant advantage is that these devices do not require the high bias currents required by the PIN diodes. In this document, a PHEMT (Pseudomorphic High Electron Mobility Transistor) switch is proposed, which was originally developed for the mobile handset market. The specification and subsequent performance plots in this patent proposal are all based on this device.

See figure 4: Performance of 8-way Switch Pages

This Figure shows the input (S_{11}) and output (S_{22}) matches together with the insertion loss (S_{21}) and isolation (S_{31}) of an optimised 8-way switch realised using ideal transmission lines. In practice, there will be a small amount of loss in the transmission lines and the connectors. The following paragraph describes the key features of the RF performance.

A brief description of the switch design was given above where the eight outputs were connected to a common point where there was a 50 ohm line of approximately $\lambda/2$ length at 2.4 GHz between the common point and each switching device. This line length was designed such that, in combination with the switching device parasitic reactance, it would simulate an open circuit point at 2.4 GHz at the common point

when the device was 'off'. Therefore, when one switching device is in the 'on' state routing the input signal to one of the 8 outputs, the other 7 simulate an open circuit at the common point at 2.4 GHz. Since the characteristic is approximately that of a $\lambda/2$ resonator, the bandwidth will be relatively narrow and determined by the impedance of the line (50 ohms in this case) and the number of switch outputs, which are 'off' (seven for an 8-way switch). Therefore, the match at 2.4 GHz is primarily determined by the transmission behaviour of these $\lambda/2$ lines. Mainly the series resistance of the switching device then determines the insertion loss to the required output port at 2.4 GHz.

At frequencies below 2.4 GHz, the $\lambda/2$ line will simulate a short circuit at the common point at 1.2 GHz ensuring no transmission occurs at this frequency and then progressively less capacitive loading down to DC. At 13.96 MHz the input and output match is primarily determined by the residual capacitance from these $\lambda/2$ lines. Also the series resistance of the switch as before largely determines the insertion loss.

When two of these 8-way switches are used in cascade to realise a 64-way switch, the performance is shown in Error! Reference source not found.. The key points to note are that the bandwidth at 13.96 MHz and 2.4 GHz for the isolation and insertion loss has contracted. This is to be expected from the cascade of two band-limited networks. The insertion loss at these two frequencies has doubled due to the cascade of two identical 8-way switches. However, it is important to note that there are now two values for the isolation. The worst-case isolation is no worse than that of the 8-way switch building block and is the

isolation between the remaining seven ports of the 8-way switch providing the output signal. The isolation to all the other 8 ports of the remaining seven 8-way switches will be twice that of a single 8-way switch.

See Figure 5: Performance of 64-way Switch

Claims

- 1. A high performance switch concept using approximate $\lambda/2$ transmission lines for realising a dual frequency multi-way switch with a large number of outputs.**
- 2. A high isolation switch design concept using a series-shunt configuration.**
- 3. A cascaded switch concept to enable optimum bandwidth at the two operating frequencies when a large number of switch outputs are required.**
- 4. A switch with high power handling capability due to its realisation using PHEMT devices.**

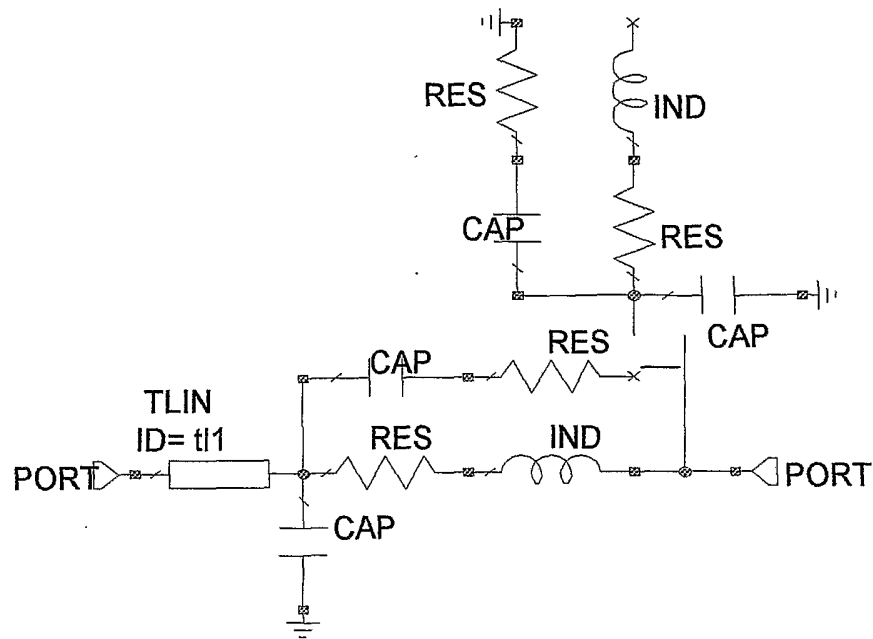


Figure 1: Circuit Diagram for the 'On' state of each Switch section

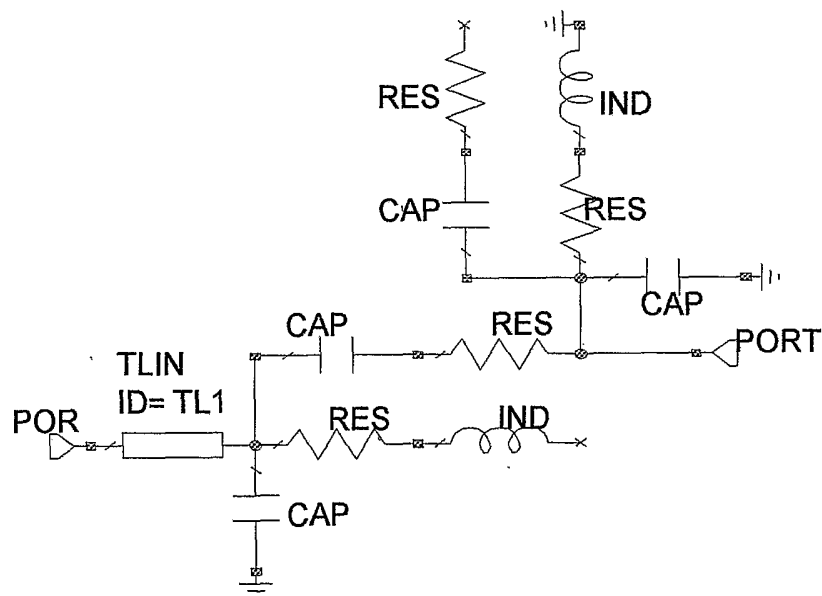


Figure 2: Circuit Diagram for the 'Off' State of each Switch Section

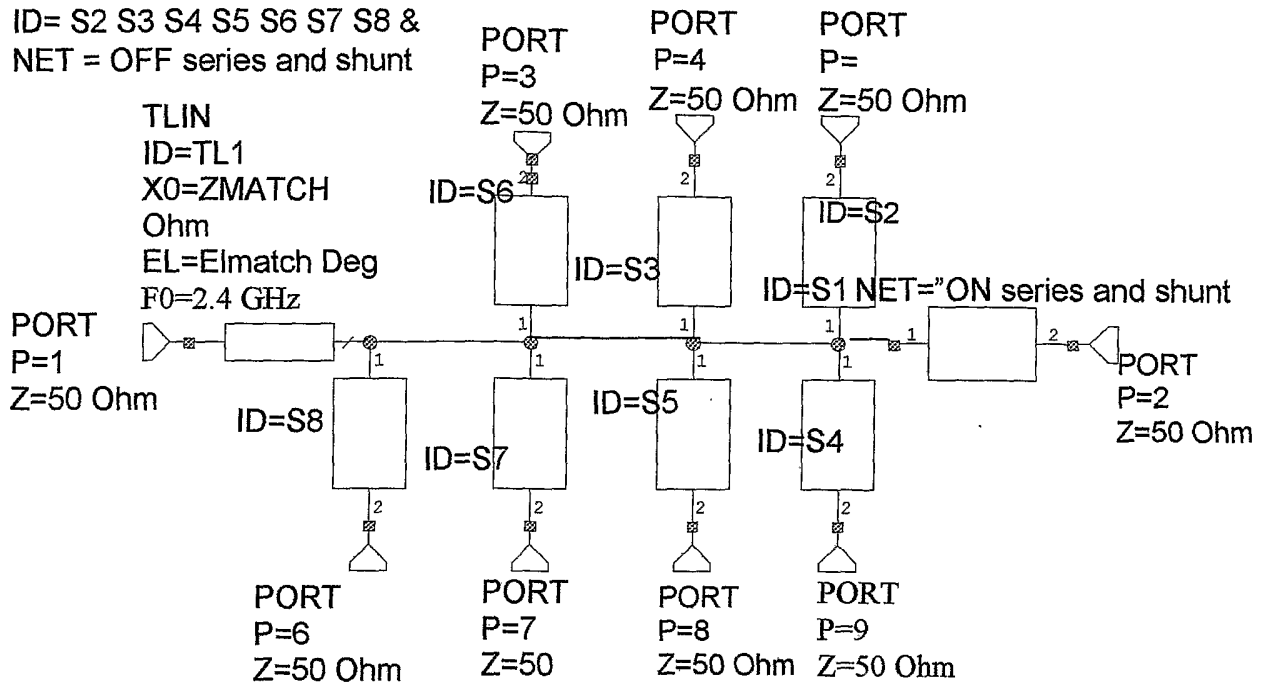


Figure 3: Block Diagram of complete 8-Way Switch

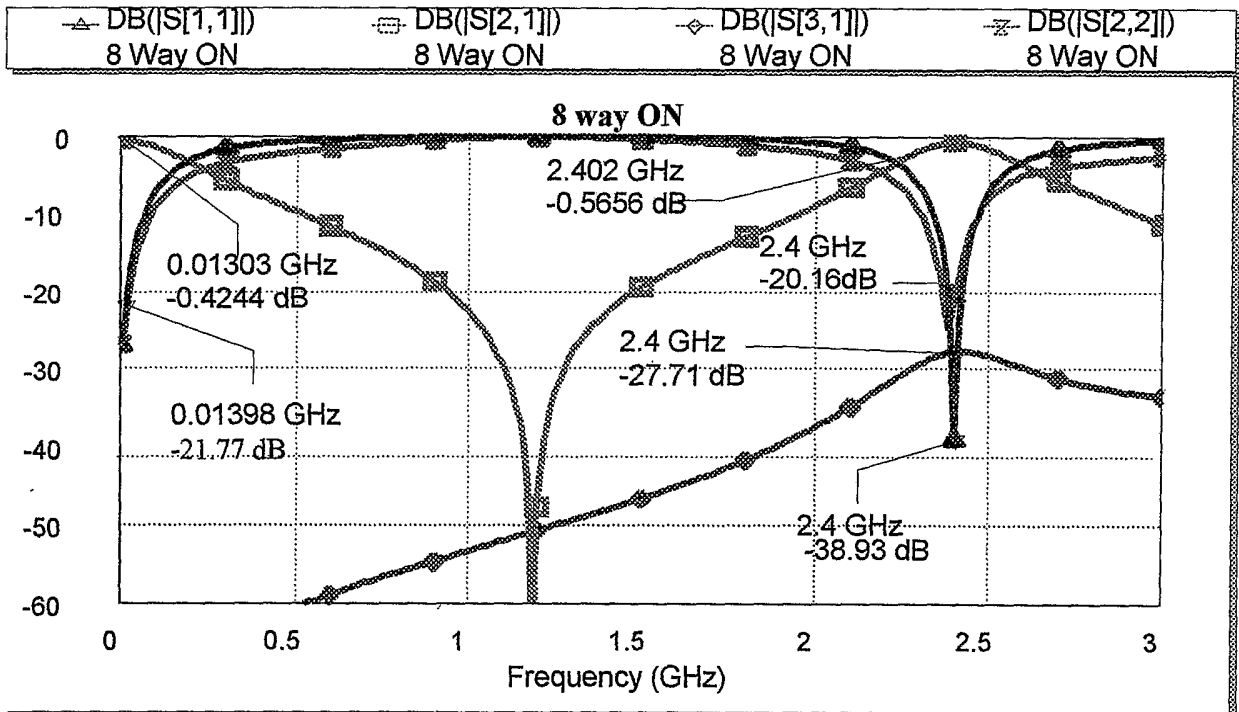


Figure 4: Performance of 8-way Switch

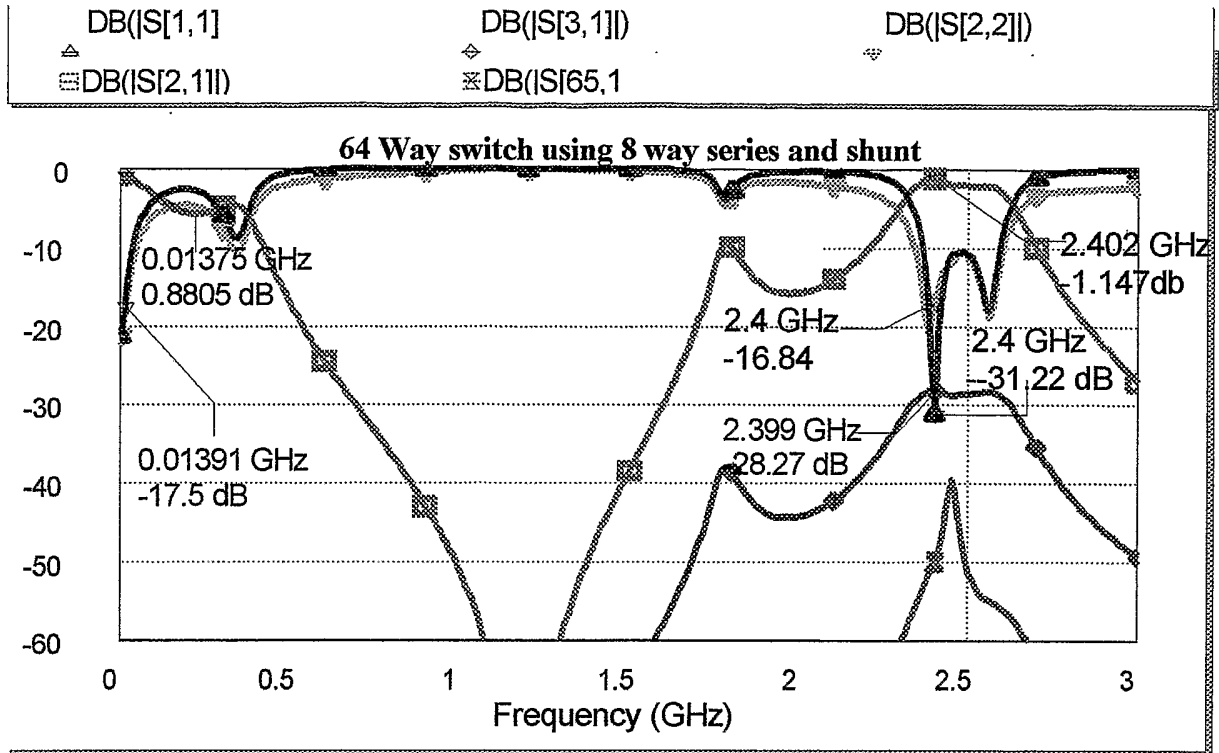


Figure 5: Performance of 64-way Switch

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB2004/001932

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01P1/15

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01P H03K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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27 August 2004

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB2004/001932

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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