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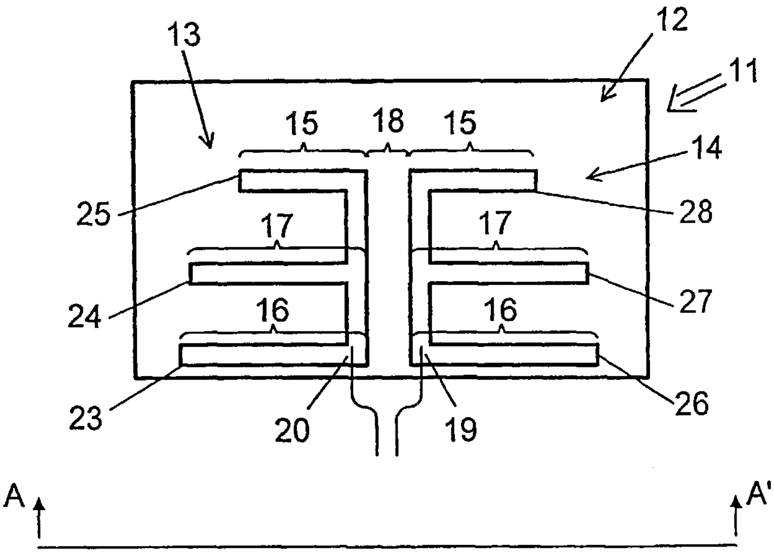
(54) Title: A COMPACT ANTENNA FOR MULTIPLE FREQUENCY OPERATION



(57) **Abstract:** An antenna intended for use in mobile communication systems is constructed as a pair of conductive comb-shaped structures on a flat rigid substrate or a flexible sheet of substrate material. It can be designed to operate in two or more distinct frequency bands according to the specifications of the communication systems.

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A COMPACT ANTENNA FOR MULTIPLE FREQUENCY OPERATION

Field of the invention

The present invention relates generally to the field of antenna design and in particular the invention relates to antennas designed to operate in two or more distinct frequency bands, and more particularly, to antennas formed as a thin conductor located on a non-conductive substrate material.

Background of the invention

Due to the developments in wireless communications, multiple radio mobile systems operating at different frequencies are gaining increasing popularity. To reduce production cost and space occupied by the antennas, it is desirable to have, for signal reception, a simple dual-frequency antenna in lieu of two separate antennas.

There are several types of dual-frequency antennas listed in patent literature. However, these are either bulky (of the reflector type), non-planar (multi-dielectric layer microstrip patch type), or with conductor printed on both sides of the plastic substrate material. It is clear that the first type (bulky reflector type) is not suitable for mobile communication application. The second (multi-layer microstrip patch), on the other hand, occupies space and is thus not suitable for use when flush-mounting of antennas is essential. Finally, the third type (conductors on both side of substrate) of antenna is not suitable for mounting against conductive materials like reinforced concrete or aluminium false ceiling.

Summary of the invention

The present invention consists in an antenna for operation in a plurality of distinct frequency bands, the antenna comprising an array of conductive elements constructed on a sheet of substrate material, the array having two generally comb-shaped structures, the comb-shaped structures each including a plurality of parallel antenna elements extending from a perpendicularly extending conductor forming a back of the comb-shaped structure, the parallel elements having lengths selected to suit the frequencies and bandwidths of operation, and the comb-shaped structures being located with the back conductors of adjacent comb-shaped structures located adjacent and parallel to one another, and the respective parallel elements projecting outwardly from the back conductors.

Preferably, the array of conductive elements is symmetrical about a line located between and parallel to the back conductors of each comb-shaped structure, and includes at least one element in each comb-shaped structure for each frequency band in which the antenna operates. There may be more than one element of each comb-shaped structure provided for a particular band of operation in which case the number of parallel elements provided in each comb-shaped structure in respect of that band, is a function of the required bandwidth and gain of the antenna in the band.

Preferably, the antenna is a two-band antenna, comprising three elements on each comb structure, one element of each comb structure being for one band of operation of the antenna, and the remaining elements of each comb structure being for the other band of operation of the antenna.

The substrate may either be a flat and rigid or semi-rigid support, such as a sheet of fibreglass printed circuit board material, a shaped rigid or semi-rigid support, such as moulded plastic case or other suitable non-conductive surface, or as a flexible sheet, such as a thin sheet or film of plastics material, or a sheet of similar non-conductive material.

In preferred embodiments, the conductors are formed on only one side of the substrate material and are preferably applied by printing or screen printing, although other methods of formation such as laminating, gluing or forming a conductive film and selectively etching are also possible.

Preferred embodiments of the invention provide an antenna for dual-frequency mobile communication systems that is compact, light-weight, of low cost, and easy to produce.

The antenna can be mounted flat against a conductive ceiling, or wall surface (such as concrete or metal), the back frame of an art painting or other decorative material, or can be made to conform to the shape of other background material (e.g., curved pillars, etc).

Brief Description of the Drawings

An embodiment of the invention will now be described by way of example, with reference to the accompanying drawings in which:

Figure 1 illustrates the general arrangement of an antenna according to an embodiment of the present invention in plan view;

Figure 2 is an edge view of the antenna of Figure 1;

Figure 3 is an example of the antenna of Figure 1 showing dimensions required to achieve a particular set of frequency responses; and

Figure 4 illustrates a performance curve of the antenna of Figure 1.

Detailed Description of Preferred Embodiments of the Invention

Referring to the accompanying drawings, embodiments of the invention are illustrated which serve to explain the construction of antennas 11 built generally in accordance with the invention. Figure 1 shows the general arrangement of embodiments of the invention in plan view. An antenna array is formed as two back to back comb-shaped conductors 13, 14, fabricated on a dielectric substrate 12. The conductors can be made of copper, aluminium, gold or any other appropriate conducting material. The dielectric substrate can be rigid or flexible. The material can be ceramic, plastics, or any other appropriate non-conductive material. The substrate thickness is not restricted, but is used as design parameter. The dimensions 15, 16, 17 of the comb-shaped conductors 13, 14 are determined by the centre frequencies of the frequency bands in which the antenna operates as well as the associated bandwidths of the multi-frequency operation. The spacing 18 between the two comb shaped conductors, on the other hand, is determined by the impedance matching requirements of the antenna.

The antenna is fed via the feed points 19, 20 as shown in Figure 1. The feeding network, while it is not part of the present invention, should be designed in conjunction with the antenna to meet specific application requirements.

Figure 2 on the other hand, shows the side view of the antenna viewed through line A-A in figure 1.

Embodiments of the invention exhibit a planar antenna with metallisation 13, 14 on only one side of the substrate 12. The substrate can be any plastics or ceramic material, depending on frequency and size requirements. However, the cheapest and most commonly available substrate is the FR4 fibreglass substrate used commercially as printed circuit board.

Referring now to Figure 3 which is a specific example of the generalised design of Figure 1, the antenna metallisation is in the shape of two comb-shaped structures 13, 14 facing back-to-back. The number of fingers 23, 24, 25, 26, 27, 28 employed depends on the gain and radiation pattern requirements. For example, as illustrated in Figure 3, an antenna is designed to have a narrow-band high-gain operation at frequency f_1, and a broad-band low-gain operation at frequency f_2, where $f_2 > f_1$. Thus, in each comb shaped structure 13, 14 two elements 23, 24, 26, 27 are needed at f_1 while only one element 25, 28 is needed at f_2, as a greater number of elements implies narrower-band and higher gain. The operation of the antenna can thus be extended to three or more bands of operations and the gain at each individual band can be adjusted by varying the number of elements resonating in that band.

Typical dimensions of a dual-band antenna constructed are given in Fig. 3. The antenna is constructed on a 1.56 mm thick FR4 substrate 12 (see Figure 1) of dimensions 130 mm x 880 mm. The length of the radiating elements (208 mm and 417 mm) are chosen to be approximately one quarter of the wavelength at the dual frequencies as follow:

$160\ \text{MHz}/c/\sqrt{\varepsilon_{eff}}/4 \approx 417\ \text{mm}$

$290\ \text{MHz}/c/\sqrt{\varepsilon_{eff}}/4 \approx 208\ \text{mm}$

where c is the speed of light and ε_{eff} is the effective dielectric constant of the microstrip conductor given by:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{10h}{w}\right)^{-0.555}$$

where h is the thickness of the substrate = 1.56 mm, w is the width of the metallisation = 19 mm, and ε_r is the dielectric constant of the substrate.

The width 31 of the metallisation is chosen such that the characteristic impedance of the strip (metallisation) is approximately 50 Ω via the following equation:

$$Z_o = 50 = \frac{120}{\sqrt{2(\varepsilon_r + 1)}}[\ln\{\frac{4h}{w} + \sqrt{16(h/w)^2 + 2}\} - \frac{\varepsilon_r - 1}{2(\varepsilon_r + 1)}\{\ln(\pi/2) + \frac{\ln(4\pi)}{\varepsilon_r}\}]$$

The spacing 32 between the two low-frequency radiating elements (s = 10 mm) and the difference between the length of these two elements (Δ = 417 mm - 398 mm = 19 mm) such that:

$$\cos(ks/\sqrt{\varepsilon_{eff}}) + j\sin(ks/\sqrt{\varepsilon_{eff}}) = Z_o \frac{-jY + jZ_o \tan(k\Delta/\sqrt{\varepsilon_{eff}})}{Z_o + Y\tan(k\Delta/\sqrt{\varepsilon_{eff}})}$$

where $Y = (Z_o \cot(2\pi f \Delta \sqrt{(\varepsilon_{eff})}/c))$, f is the frequency of operation and c is the speed of light.

The spacing 33 between the two groups of radiators (20 mm) is chosen to be slightly larger than the width of the strip (metallisation 19 mm).

The spacing between the two Comb- shapes 13, 14 (sp = 2 mm) is chosen such that the characteristic impedance of the slot thus formed has a 50 Ω impedance for easy matching with the coaxial cable feed to be connected to it.

Thus:

$50 \approx 113.19 - 53.55\log(\varepsilon_r) + 1.25(sp/h)\{114.59-51.88\log(\varepsilon_r)\} + 20\{(sp/h)-0.2\}\{1 - (sp/h)\} - \{0.15 + 0.23\log(\varepsilon_r) + (sp/h)[-0.79 + 2.07\log(\varepsilon_r)]\}\{10.25 - 5\log(\varepsilon_r) + (sp/h)\{2.1 - 1.42\log(\varepsilon_r)\} - 100(hf/c)\}^2$

The performance of such an antenna is given by the impedance graph in Fig. 4, from which it can be seen that the objectives of a narrow-band high-gain radiation at about 150 - 170 MHz and a broad-band low-gain radiation at about 280 - 300 MHz have been well achieved.

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

Claims:

1. An antenna for operation in a plurality of distinct frequency bands, the antenna having an array of conductive elements constructed on a sheet of substrate material, the array comprising two generally comb-shaped structures, the comb-shaped structures each including a plurality of parallel antenna elements extending from a perpendicularly extending conductor forming a back of the comb-shaped structure, the parallel elements having lengths selected to suit the frequencies and bandwidths of operation, and the comb-shaped structures being located with the back conductors of adjacent comb-shaped structures located adjacent and parallel to one another, and the respective parallel elements projecting outwardly from the back conductors.

2. The antenna as claimed in claim 1, wherein the array of conductive elements is symmetrical about a line located between and parallel to the back conductors of each comb-shaped structure.

3. The antenna as claimed in claim 1, wherein the array of conductive elements includes at least one element in each comb-shaped structure for each frequency band in which the antenna operates.

4. The antenna as claimed in claim 1, wherein, for each band of operation of the antenna, the number of parallel elements provided in each comb-shaped structure in respect of that band, is a function of the required bandwidth and gain of the antenna in the band.

5. The antenna as claimed in claim 1, wherein, the antenna is a two-band antenna, comprising three elements on each comb structure, one element of each comb structure being for one band of operation of the antenna, and the remaining elements of each comb structure being for the other band of operation of the antenna.

6. The antenna as claimed in claim 5, wherein the array of conductive elements is formed on only one side of the substrate material.

7. The antenna as claimed in claim 6, wherein the array of conductive elements is applied to the substrate by printing.

8. The antenna as claimed in claim 6, wherein the array of conductive elements is applied to the substrate by screen printing.

9. The antenna as claimed in claim 6, wherein the array of conductive elements is applied to the substrate by laminating the conductive array to the substrate.

10. The antenna as claimed in claim 6, wherein the array of conductive elements is applied to the substrate by gluing the conductive array to the substrate.

11. The antenna as claimed in claim 6, wherein the array of conductive elements is applied to the substrate by forming a conductive film bonded to the substrate and selectively etching to pattern the antenna into the film.

12. The antenna as claimed in claim 8, wherein the substrate is a flat, rigid or semi-rigid structure, with a non-conductive surface.

13. The antenna as claimed in claim 8, wherein the substrate is fibreglass printed circuit board material.

14. The antenna as claimed in claim 8, wherein the substrate is a shaped rigid or semi-rigid structure, with a non-conductive surface.

15. The antenna as claimed in claim 8, wherein the substrate is a moulded plastic structure.

16. The antenna as claimed in claim 8, wherein the substrate is a sheet or film of non-conductive flexible material.

17. The antenna as claimed in claim 8, wherein the substrate is a thin sheet or film of plastics material.

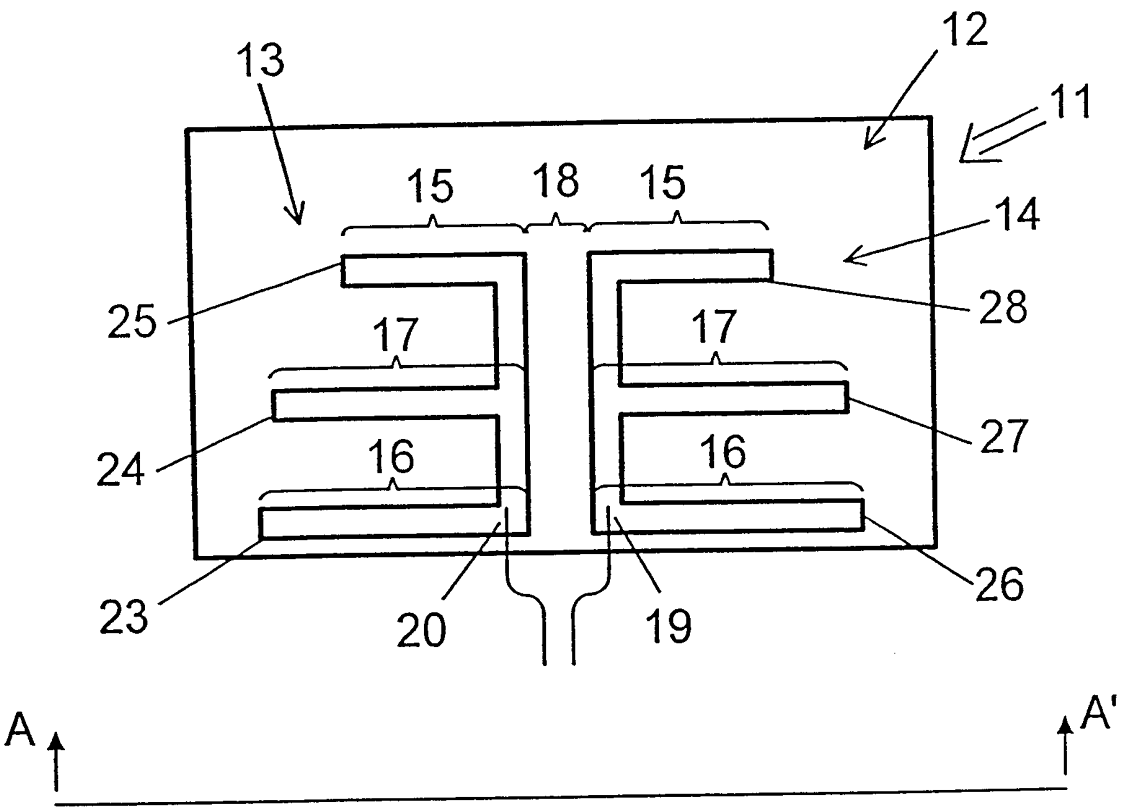

Figure 1

side view AA'

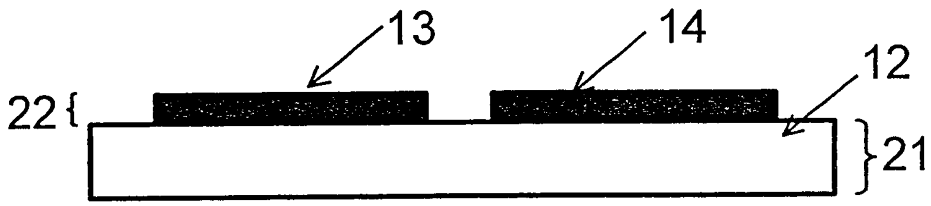

Figure 2

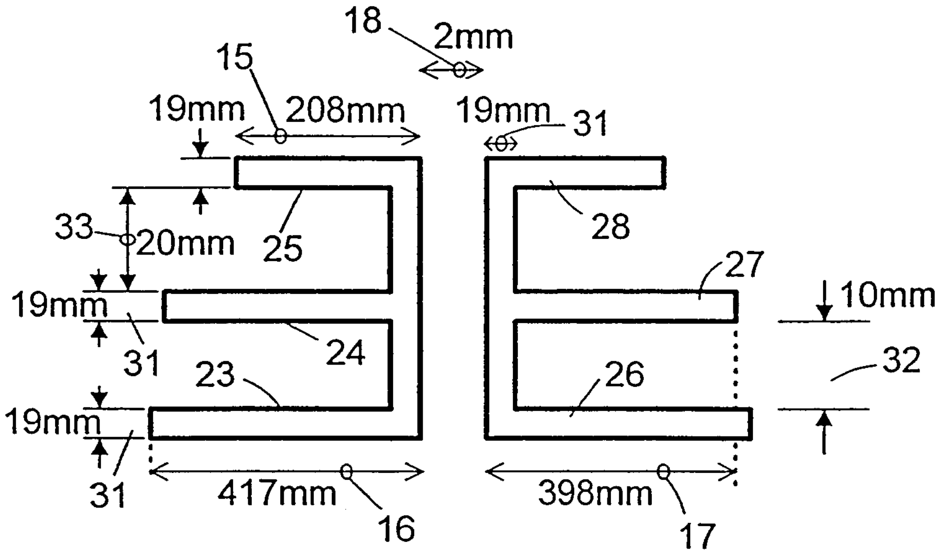
18
2mm
15
19mm
208mm
19mm
31
33
20mm
25
28
27
10mm
19mm
31
24
23
26
32
19mm
31
417mm
16
398mm
17

Figure 3

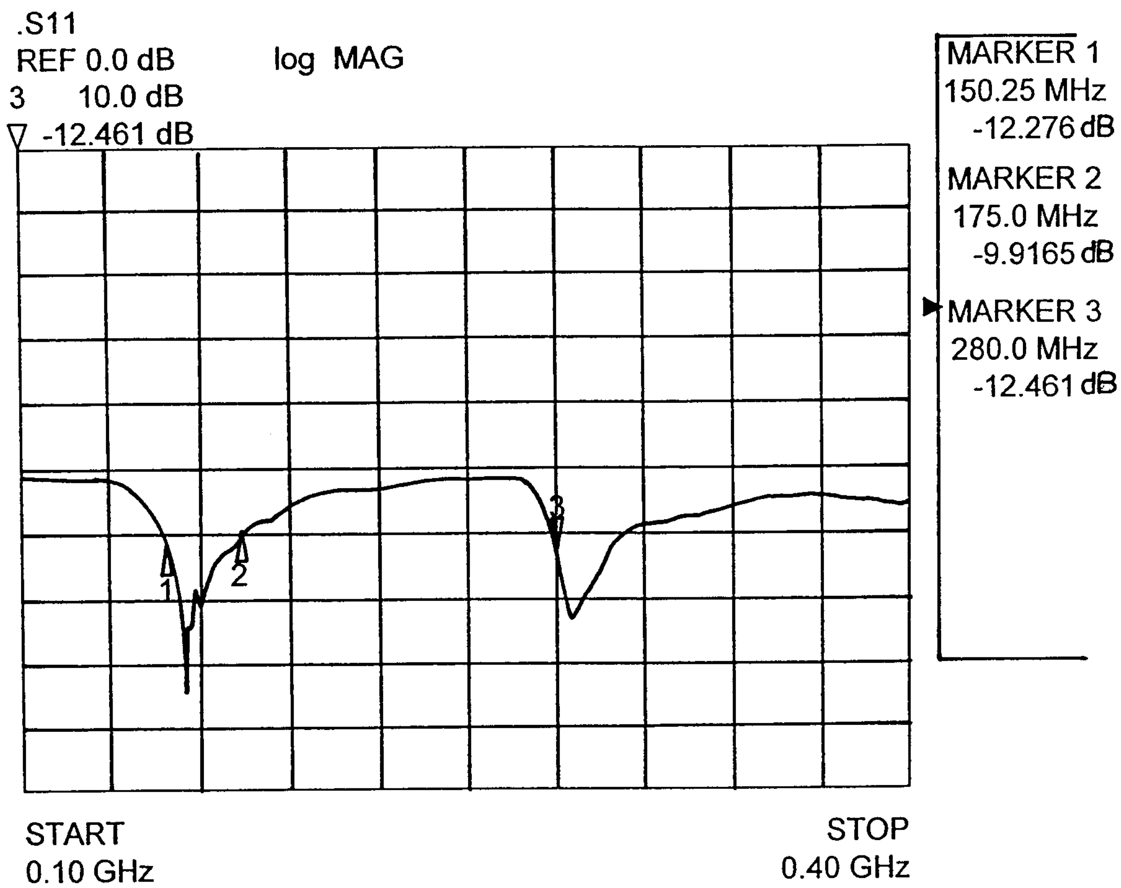
.S11
REF 0.0 dB
log MAG
3 10.0 dB
▽ -12.461 dB
MARKER 1
150.25 MHz
-12.276 dB
MARKER 2
175.0 MHz
-9.9165 dB
MARKER 3
280.0 MHz
-12.461 dB
1
2
3
START
0.10 GHz
STOP
0.40 GHz

Figure 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG 00/00121

CLASSIFICATION OF SUBJECT MATTER

IPC[7]: H01Q 5/02, 9/16, 1/38

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]: H01Q

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 practicable, search terms used)

WPI, EPODOC, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5262791 A (TSUDA et al.) 16 November 1993 (16.11.93) the whole document.	1-17
A	EP 0342175 B1 (COMSAT) 23 March 1996 (23.03.96) figs. 1,2,5,8 and corresponding text.	1
A	JP 57 188108 A (MITSUBISHI) 19 November 1982 (19.11.82) abstract, figs.	1
A	DE 3613258 A1 (LICENTIA) 22 October 1987 (22.10.87) figs. 1,3, claims 1,2, column 3, line 9 and 50.	1
A	JP 05 347509 A (MATSUSHITA) 27 December 1993 (27.12.93) abstract, figs.	1
A	JP 05 347510 A (MATSUSHITA) 27 December 1993 (27.12.93) abstract, figs.	1

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

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„&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 November 2000 (28.11.2000)	13 February 2001 (13.02.2001)

Name and mailing adress of the ISA/AT	Authorized officer
Austrian Patent Office Kohlmarkt 8-10; A-1014 Vienna Facsimile No. 1/53424/535	HEINICH Telephone No. 1/53424/454

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/SG 00/00121

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