CYLINDRICAL MULTI-SECTOR ANTENNA WITH SELF-SELECTING SWITCHING CIRCUIT

Tomohiro SEKI, and Toshikazu HORI
Nippon Telegraph and Telephone Corporation
1-1 Hikari-no-oka, Yokosuka, Kanagawa 239-0847, Japan
E-mail: t.seki@ieee.org

1. Introduction

Wide-band indoor communication systems such as wireless LANs are being developed in the quasi-millimeter and millimeter-wave frequency bands [1],[2]. Such systems must offer data transmission rates of 10 Mbps or more, thus making anti-multipath and anti-shadowing techniques necessary. One solution is to narrow the beam width and to suppress the side lobe characteristics of the base station and personal station antennas [3]. As the frequency increases, antennas that realize a high gain to narrow the beam width must be used because the design margin decreases. However, when phased-array antennas or beam-switching antennas are employed in order to track the beams, the loss incurred by the phase-shifter and the beam-switching circuits used in the antenna configurations cannot be ignored at these frequencies. Accordingly, it is useful to use sector antennas to simplify the structure. However, the diameter of a sector antenna rapidly increases with the number of sectors [4],[5]. One solution is to use a Wullenweber type antenna, which easily forms narrow beams [6],[7]. Unfortunately, because a phase shifter and switching circuits are necessary, circuit realization becomes problematic when the number of simultaneously fed antenna elements increases due to increased circuit complexity. Moreover, since the phase value of the location of the antenna element in the projection plane is odd, the application of a bit phase shifter is difficult [8].

In this paper, we propose a cylindrical multi-sector antenna that has a diameter less than half that of the conventional multi-sector antenna, which is constructed with one element antenna such as a corner reflector antenna per sector. This new antenna has a novel self-selecting switching circuit that realizes phased-array operation such as controlling the common sector switch circuit and that suppresses the side lobe level by attenuating the switching circuit to taper the feeding amplitude. Furthermore, a prototype switching circuit for the 12-sector antenna is introduced to verify this feeding circuit and antenna design.

2. Configuration of cylindrical multi-sector antenna

The cylindrical multi-sector antenna structure, which is suited to the proposed feeding circuits, is shown in Fig. 1. Since the inside of the antenna structure is useful in housing the RF module, we selected a 2n sub-array antenna configuration to construct the cylindrical array, where n is the number of the sectored zones. In this figure, the sub-array antenna comprised three microstrip antenna elements for example. This paper also describes the calculated characteristics of the antenna. The antenna was constructed by setting double the number of sub-arrays equal to the number of sectors along the circumference, and it fed three adjacent sub-array antennas simultaneously. Figure 2 shows the calculated results of the half-power beam width, which is calculated in the horizontal plane, and the side lobe level versus the number of sectors for this design calculated assuming that a microstrip antenna with a finite ground plane was used as the element antenna when the phase value of the location of the antenna

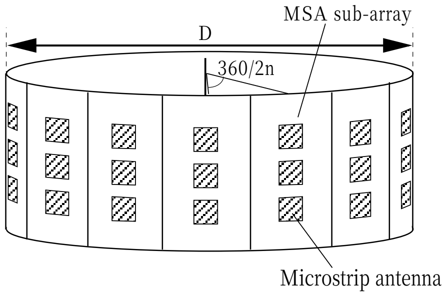

Fig. 1 Antenna structure

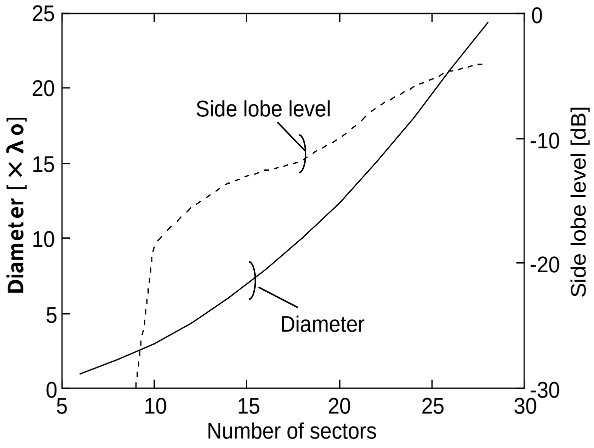

Fig. 2 Calculated antenna diameter and side lobe level versus number of sectors

element in the projection plane was adjusted to equal. Figure 2 shows that when the number of sectors was less than 20, the side lobe level was less than -10 dB. However, when the number of sectors was small such as four, a single element microstrip antenna can be employed, although it is not effective.

Next, the cylindrical 12-sector antenna design is described as a concrete example. Figure 3 plots the half-power beam width and the side lobe level versus the antenna diameter for this design calculated assuming that a microstrip antenna with a finite ground plane was used as the element antenna. This configuration has 24-element sub-array antennas along the circumference that feed three sub-array antennas simultaneously. If 12-element antennas, the number of which equaling the number of sectors, are arranged along the circumference and form beams in the direction of each element when simultaneously feeding three adjacent sub-array antennas, the horizontal beam width can be determined by the antenna diameter, which was equivalent to 2.4 free space wave lengths. This structure was difficult to construct due to the complicated feeding circuits that were required. The feeding phase of each sub-array antenna required that it be switched. In Fig. 3, when the diameter was 4.5 free space wave lengths, the half-power beam width was 30 degrees and the side lobe level was less than -13 dB.

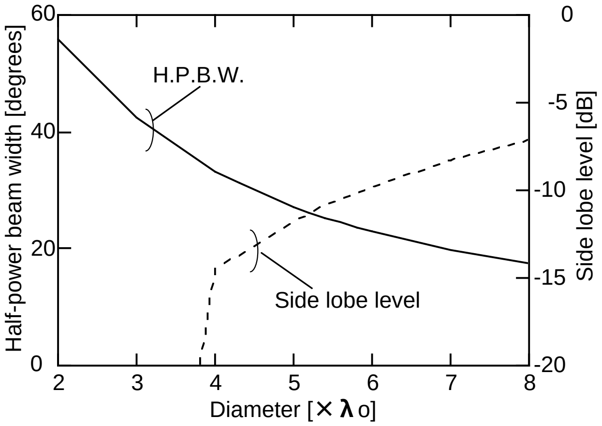

Fig. 3 Calculated half power beam width and side lobe level versus antenna diameter

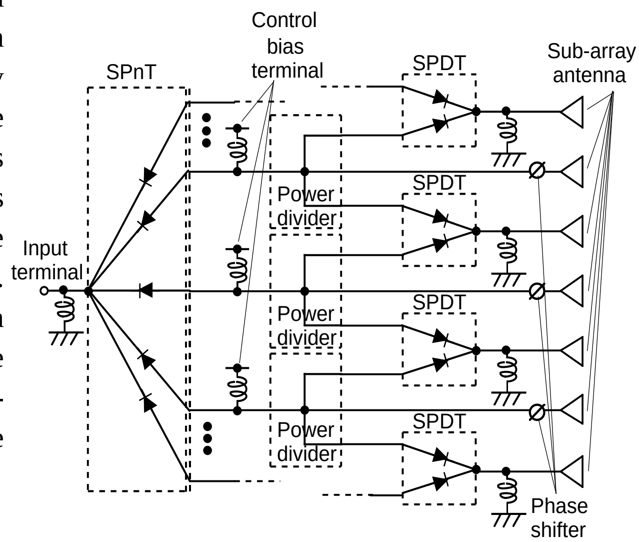

Fig. 4 Proposed feeding network circuit

3. Self-selecting switching circuit

Figure 4 shows the proposed feeding circuit. In this figure, the feeding circuit was controlled by biasing the bias control terminal. One bias control terminal in the direction of the desired sector biased the positive voltage to drive the switch diode and the other bias control terminals biased the negative voltage to interrupt the reverse current. Accordingly, this feeding circuit fed three sub-array antennas simultaneously to realize phased-array antenna operation. The switch circuit selected the desired sector and the circuit then automatically drove the set of three sub-array antennas. This feeding circuit structure was useful in simply adjusting the feeding phase of three sub-array antennas.

As an example, Fig. 5 shows the circuit pattern with pin diode switches. The figure clarifies that the circuit can be easily arranged on a planar substrate. However, the insertion loss of the switching circuit must be considered for the common use microstrip antennas. Figure 6 shows the calculated effects on the half-power beam width and the side lobe level of the switch insertion loss. As the switch loss increased, the main effect decreased the side lobe level. In other words, the insertion loss did not cause a problem except for a slight decrease in the antenna gain.

4. Characteristics of cylindrical 12-sector antenna with self-selecting switching circuit

To verify this antenna design, we manufactured a prototype self-selecting switching circuit of a 12-sector antenna for 19-GHz operation and measured its feeding characteristics. The antenna diameter of 4.5 free space wave lengths was assumed. In this prototype feeding circuit, we adopted an HPND-4018 pin diode as the switching circuit, and we used the switching circuit with a two-stage in-series connection to realize adequate isolation characteristics.

First, we describe the measured output characteristics of the feeding circuit with phase adjustment of the semi-rigid cable. The relative feeding-amplitude levels of the three terminals for the sub-array antennas were -1.3 dB, 0.0 dB and -1.4 dB, respectively. The feeding relative phase values were 36.5 degrees, 0.0 degree, and 44.2 degrees in sequence. Additionally, the insertion loss of the SP12T switch circuit was approximately 1.9 dB, and the loss of the switch circuit on the divergence line was approximately 1.9 dB at 19-

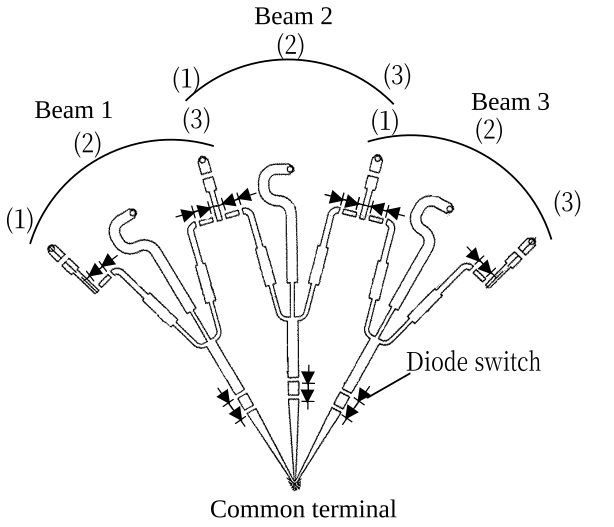

Fig. 5 Example metal pattern of the feeding network circuit

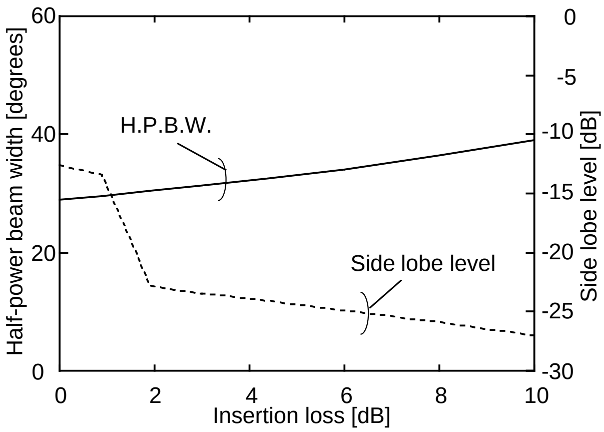

Fig. 6 Calculated side lobe level and half-power beam width versus insertion loss of the feeding network circuit

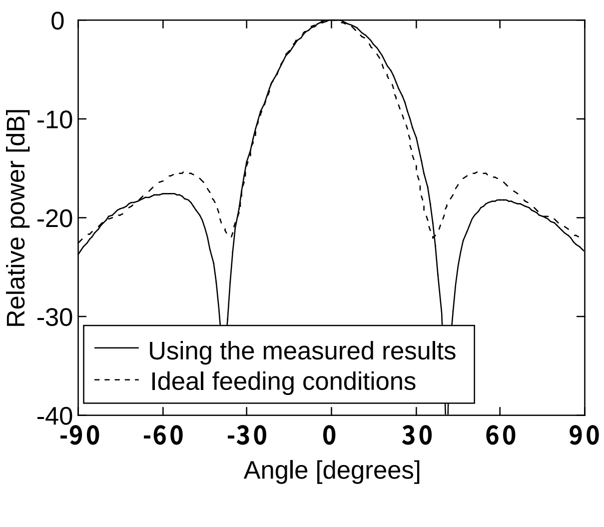

Fig. 7 Calculated horizontal plane radiation patterns using the measured result of the feeding circuit

GHz. Next, the calculated radiation pattern of the horizontal plane using the measured results of the feeding circuits is shown in Fig. 7. The solid line represents the results using the measured feeding conditions of the self-selecting switching circuit and the dotted line represents the results using the equivalent feeding phase in the projection plane and the equivalent amplitude. This figure confirms that the half-power beam width was 31.1 degrees and the side lobe level was -17.5 dB. It is clear that the extent of the main lobe was 1.3 degrees and the improvement in the side lobe level was 2.1 dB. For reference, Photo. 1 shows the prototype antenna on a notebook-type personal computer display. This antenna has a diameter of 70 mm and is 40 mm tall.

Photo. 1 Photograph of prototype cylindrical 12-sector antenna

5. Conclusion

We proposed a self-selecting switching circuit for the feeding circuit of a phased-array type sector antenna that is easily controlled. Moreover, the diameter of the cylindrical multi-sector antenna is less than half that of the conventional multi-sector antenna, which is constructed with a corner reflector antenna. The side lobe level was improved due to a tapered feeding amplitude achieved by attenuating the switching circuit. Furthermore, to confirm the efficiency of the self-selecting switching circuit, a prototype feeding circuit for 19-GHz operation was fabricated and we confirmed that the feeding circuit exhibited good performance for the 12-sector antenna. The prototype antenna size has a diameter of 70 mm and is 40 mm tall.

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