Wideband frangible monopole for radio monitoring

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***Abstract-* In preparation for an urban environment radio localization demonstration using a Direction of Arrival system carried by a Zeppelin NT airship, some initial flights to check the reference transmitter broadcast power at altitude were conducted. A small handheld monopole antenna was required for 1.8 to 2.2GHz which could safely be used in the cabin of the Zeppelin NT airship in flight. The soft metal – no sharps monopole antenna had 29% bandwidth and was successfully used for 2 flights.**

I. Introduction

A Direction of Arrival (DOA) system for stratospheric unmanned aircraft to localize radio transmitters on the ground was proposed [1-4]. Potential localization applications were finding cell phones post-disaster, distress beacons, illegal radio transmitters, wildlife tracking, and high speed car positioning, all of which required accuracies of the order of meters. A major complication was that the stratospheric unmanned aircraft were flexible causing the array elements spread along the wingspan to be constantly in relative motion. Placing co-band reference transmitters on the ground in the vicinity of the target transmitter allowed for a simplification of the mathematics and removed the requirement to precisely know the positions of the array elements [1-4], Figure 1. The ground reference transmitters could be purpose laid beacons or as mundane as existing 3G cell phone base stations. Four 3G bands were considered for ground reference stations, Table 1.

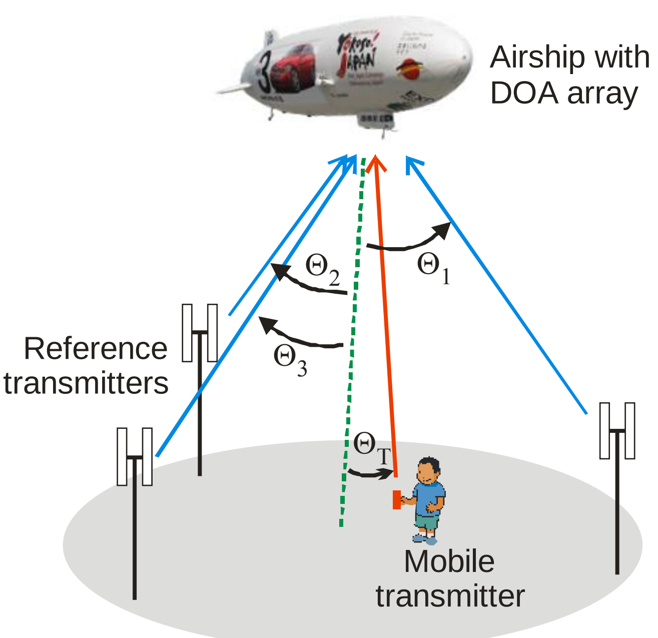

Figure 1. System concept for airborne Direction of Arrival system onboard an airship using 3G cell phone base stations as reference transmitters.

TABLE I
3G Frequency Allocations in Japan

Bands	Frequencies (MHz)
VI & XIX	875 - 888
VIII	925-960
IX	1,845 – 1,880
I	2,110 – 2,170

Figure 2. Ground handling of the Zeppelin NT airship at Honda Airport, Okegawa, Saitama Prefecture; note the relative size of the gondola.

A Zeppelin NT airship was available for airborne radio communications demonstrations and field trials during the Japanese 2006/2007 and 2007/2008 financial years, Figure 2. As an airborne communications platform this 75m long airship had excellent characteristics, been capable of station keeping at 1,000m altitude, having a spacious cabin seating 12, and having a toilet enabling full-day field trials. Additionally, the Zeppelin NT airship was of particular interest for post-disaster recovery as it was a stable and quiet platform with no downdraft (contrast to a helicopter), and was perfect for observations of the ground either by human spotters or using high resolution digital camera. However, antennas for specific field trials could not be attached to the outside of the gondola due to flight worthiness certificate restrictions. The project plan is given as Table 2, and required 2 initial flights to confirm the reception of sufficient signal strength at an altitude of 1,000m. A small omni-directional antenna attached to a portable spectrum analyzer was to be used for these 2 flights, which raised a number of safety concerns related to handling a monopole antenna in the cabin of a vehicle in motion.

TABLE II
PROJECT SCHEDULE

Flight	Date	Antenna used
1	August 2006	This work
2	August 2006	This work
3	January 2007	Medium gain [8]
4	January 2008	4x4 patch array [9]

The Zeppelin NT airship in flight rolled and pitched gently in a similar fashion to a yacht. As sudden vehicle movement were thus discounted in the risk analysis, the main safety concern were accidents from human clumsiness working in a confined space such as tripping on improperly stowed equipment. Two possible types of injury while handling a monopole antenna were expected:

- stick-stabbing wounds from been impaled from a straight fall onto a monopole,
- slash-cut from brushing past a thin metal ground plane

The first injury type would be mitigated by using soft and thin metals, and an antenna structure which would readily collapse and crumple if fallen on by an adult. For the second type of injury, the number of sharp corners should be minimized and all edges rounded by filing.

The full bandwidth from the bottom of the 3G VI Band to the top of the I Band was 85.1%, Table 1, which would conventionally be met by a multi-band antenna based on microstrip technology with passive matching elements, such as [5]. However, the rigidity of the microstrip substrate would violate the frangibility requirement. Having separate antennas for the lower VI/XIX and VIII bands and upper IX and I bands was more readily achievable by a wideband monopole design. The bandwidth for the IX and I bands was 16.1%. A flat thin metal square monopole such as [6] would satisfy the $S_{11} \leq -10$dB bandwidth, but fail on the safety requirement due the square monopole been akin to a blade. In contrast, a thin metal folded monopole by the same authors [7] was enclosed and judged to be less likely to inflict slash-cut injuries, Figure 3.

II. WIDE-BAND METAL-PLATE MONOPOLE ANTENNA

The reported VSWR 2:1 bandwidth for a monopole made of folded thin sheet metal was 110%, [7]. Also, the reported lower bound of the VSWR 2:1 bandwidth was 1.92GHz, which only need be moved 100MHz lower to encompass the 3G IX band.

Simulating the antenna in FEKO™ gave a return loss characteristic loosely resembling the reported experimental measurements but significantly having narrower bandwidth and a distinct dual resonance, Figure 4. The currents on petals of the monopole tended to hug the sides of the petals across the entire bandwidth studied, Figure 5. Best return loss occurred when the currents at the bottom of the petals were well below the peak current, with the corners (left side of Figure 5) having low values.

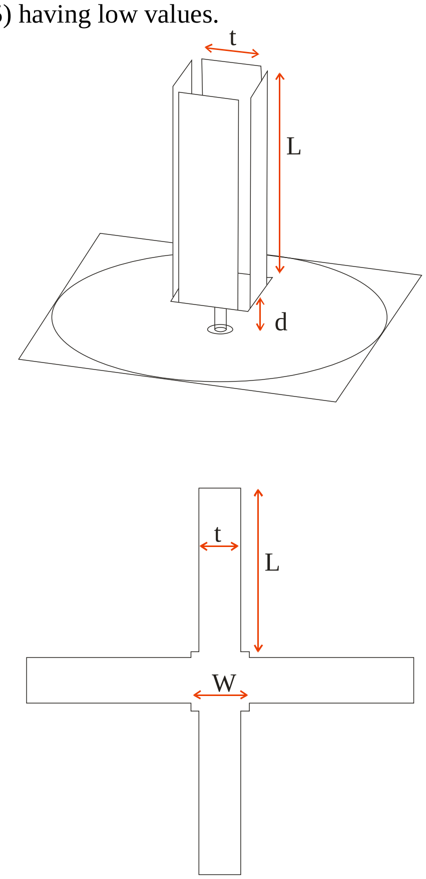

Figure 3. The metal-plate monopole antenna, derived from Figure 1 of [7].

TABLE III
ANTENNA DIMENSIONS

Dimension	Original [7]	This work
L	23	48
W	8	16
t	6	11
d	4.5	5
Ground Plane Side	150mm square	150mm circle

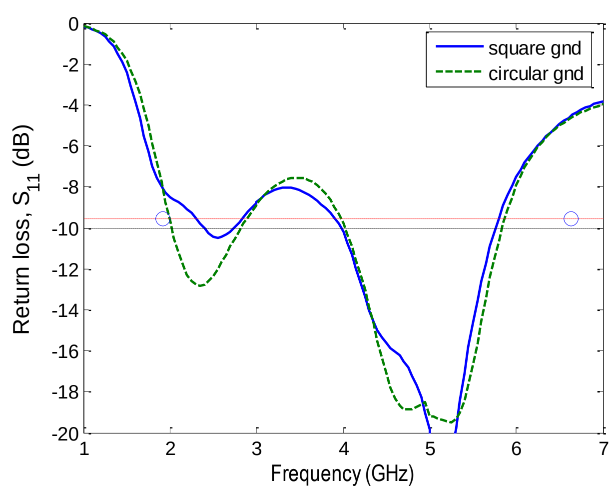

Figure 4. Return loss of metal-plate monopole antenna, from FEKO™.

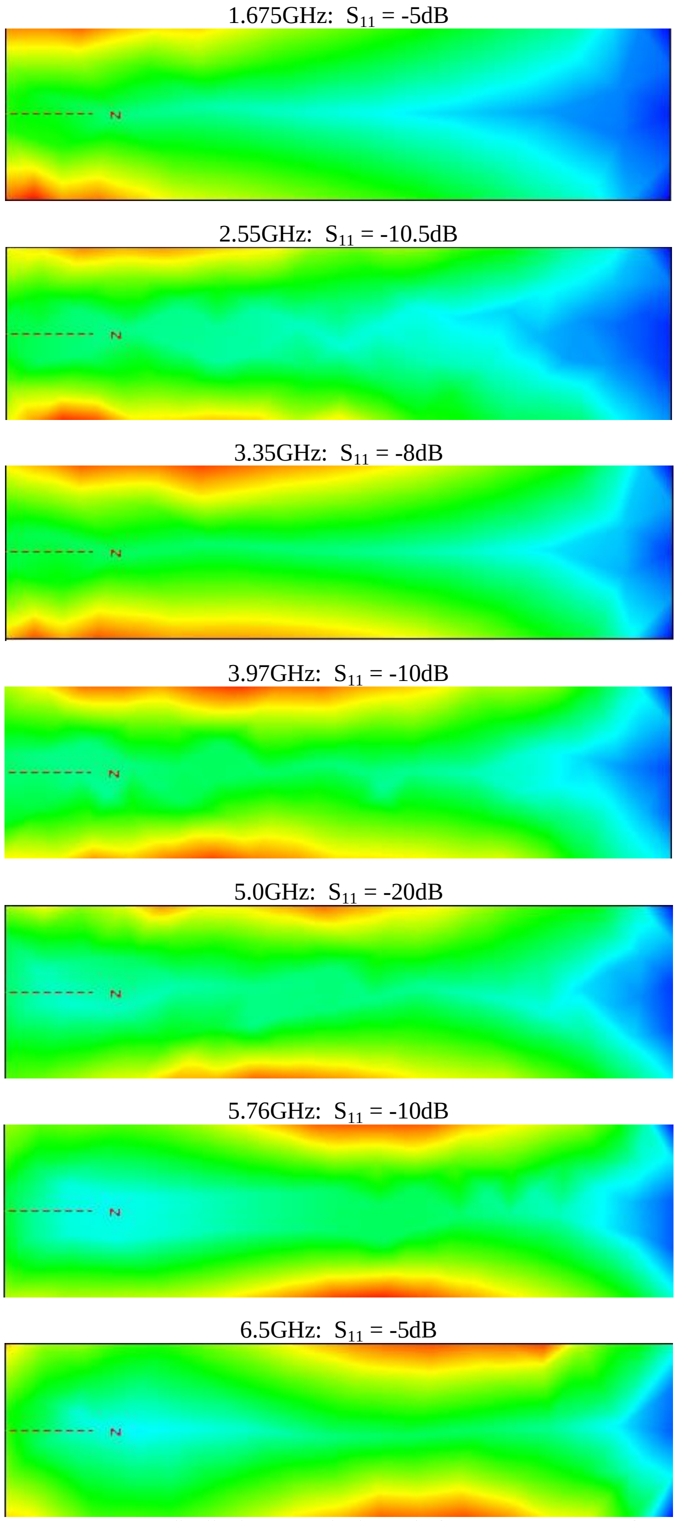

Figure 5. Current distributions on a single petal, from FEKO™; base of the petal on the left, top on the right.

III. Circular Ground Plane Effect

Having achieved a rough repeat of the antenna characteristics reported in [7] and gained some insight into mode of operation, the design was adapted for the application described above.

The first step was to change the ground plane from a 150mm sided square to a 150mm diameter circle, thus eliminating the corners. No radical changes were seen in the return loss, Figure 4. The first resonance around 2.1GHz improved in depth, and moved a little higher in frequency.

The second step was to move the first resonance lower in frequency so that the 3G IX and I bands would be covered. This required a close to doubling of the dimensions of the monopole, Table 3 and Figure 6. This was in no way a disadvantage in that the larger monopole was easier the cut out of 0.3mm thickness brass by hand. The radiation patterns were likewise satisfactory, exhibiting a typical monopole radiation pattern shape at the centers of both IX and I bands, Figure 7.

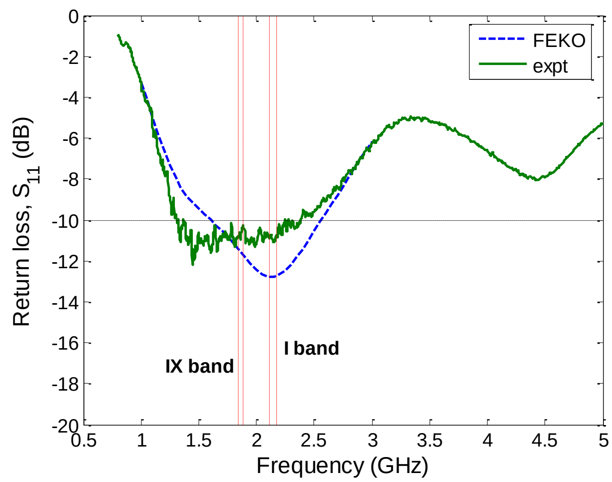

Figure 6. Return loss of the metal-plate antenna with a circular ground plane.

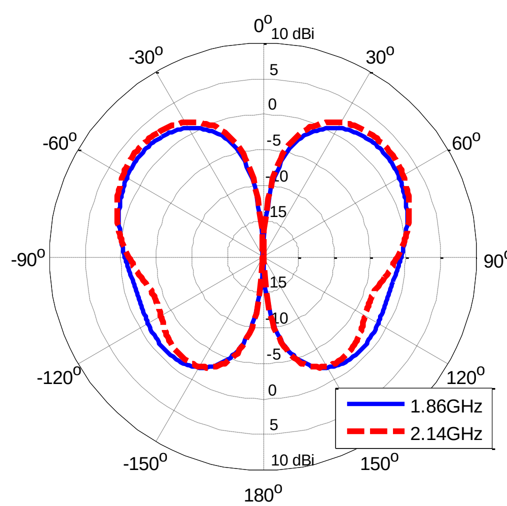

Figure 7. Radiation patterns of the metal-plate antenna with a circular ground plane, from FEKO™.

The ground plane for the metal plate monopole was cut from 0.5mm copper, which was thin and soft enough to crumple if fallen on. This handheld antenna was used for 2 demonstration flights in August 2006.

Figure 8. Antenna in use while flying at 1,000m altitude.

IV. CONCLUSIONS

A wideband frangible monopole antenna was made from thin metal sheeting, and proved its worth as a handheld antenna for receiving 3G cell phone signals during 2 demonstration flights in a Zeppelin NT airship. It was found that the monopole antenna dimensions had to be roughly doubled to effect a small downward shift in resonant frequency.

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