CONTRIBUTIONS TO THE UK MICROWAVE LANDING SYSTEM RESEARCH AND D-ETC(U)

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Volume 2.

by

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VOLUME 2

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Fig 1.1 Coverage requirements for MLS

Azimuth coverage

Vertical coverage
Fig 2.1

Source motion speed $V$

Positive Doppler shift

$F_D = \frac{V \sin \theta}{\lambda}$

Negative Doppler shift

Source wavelength $\lambda$

Fig 2.1 Doppler effect
Fig. 2.2 Basic system - block diagram

- **Transmitter**
  - Frequency sources
  - Antenna
  - Coding generator

- **Equations**
  - Doppler code frequency: $F_D = \frac{V \sin \theta}{\lambda}$
  - Basic transmission frequency: $F_C$
  - Offset frequency: $F_O$
  - Offset drift: $\delta_1 F = \text{Tx drift}$
  - Doppler shift due to Rx motion: $\delta_2 F$
  - Rx drift: $\delta_3 F$

- **Diagram**
  - Signals flow through different blocks such as RF, IF, Detector, and Frequency measurement to produce angle output in digital and analogue forms.
Fig 2.3

Reference transmission \( \exp j \omega_R t \)
Array signal 'left to right' \( \exp j (\omega_A t + \alpha) \)
Array signal 'right to left' \( \exp j (\omega_A t + \beta) \)

\[ d = D\lambda \quad \ell = L\lambda \]
Fig 2.4 Doppler signal waveforms

CONTINUOUS LINEAR SOURCE MOVEMENT

SINGLE LINEAR SCAN

SINGLE STEP SCAN
Fig 2.5 Doppler signal spectra

(a) Continuous linear source movement

Amplitude

\[ F_0 \quad F_0 + \frac{V \sin \theta}{\lambda} \]

(b) Single linear scan over distance \( L \lambda \)

(c) Single step scan over array length \( L \lambda \)
Fig 2.6 Typical angle transmission formats

Key:
- Received reference signal
- Received array signal
Fig 2.7  Fixed and commutated reference systems
Fig 2.8 The basic DMLS ground system
2.9a Azimuth system

2.9b Elevation system

Fig 2.9a&b Received difference signal spectra
Fig 2.10

System coverage

Coverage
sector filter

True direct signal

Frequency

$\pm 40^\circ$

$0^\circ$

$-80^\circ$

Fig 2.10 Doppler signal with multipath
Fig 2.11  Separation of wanted signal using frequency cell
Fig 3.1 Hybrid format
Fig 3.2

Fig 3.2 Frequency interchange method of providing offset frequency

Key:
- Frequency band occupied by all possible received commutated frequencies.
- Commutated array feed frequency
- Reference frequency
Fig 3.3 Azimuth sub-channel frequencies (kHz)

Fig 3.4 Elevation sub-channel frequencies (kHz)
Fig 3.5  120 wavelength azimuth antenna
Fig 3.6 Azimuth transmitter block diagram
Fig 3.7 Azimuth facilities blending and shaping
Fig 3.8
Fig 3.9 Monopole on 3 ft counterpoise (vertical pattern)
Fig 3.10 Monopole on 3 ft counterpoise (horizontal pattern)
Fig 3.11

Transmitted signal phase and amplitude spread (approach azimuth)
Fig 3.13  90 wavelength elevation array
Fig 3.14

Array element azimuth radiation pattern

Radiated power, dB
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90

Azimuth Angle, Degrees
Fig 3.15

Array element elevation radiation pattern

Radiated power dB

Elevation angle, degrees
Fig 3.16 Reference antenna array factors
Fig 3.18 Curve of insertion loss for 4-way switching module
Fig 3.19  Theoretical and practical curves of isolation for 4-way switching module
Fig 3.21 Elevation field monitor mounting
Fig 3.22: Data transmitter block diagram

To monopole antenna

20 dB

20 watt TWT

Power supply

Detector

5 volt logic sync pulses

Pin modulator

Feedback circuit

Tone generator

20 dB

Klystron

Power supply

Synchroniser

FM or $\phi$ mod I/P

IF Ref I/P
Fig 3.24 Outline block diagram of type S receiver
Fig 3.25  Sine/cosine tracker system detail diagram
Fig 4.1a Close and long range approach azimuth test points
Fig 4.1b Cross runway approach azimuth test points
Fig 4.2  Approach azimuth static test GS56, position F6
Fig 4.3a  Approach azimuth. Vehicle run along test runway centre line. Mast height 20 ft
Fig 4.3b  Approach azimuth. Vehicle run along test runway centre line. Mast height 20 ft
Fig 4.3c  Approach azimuth. Vehicle run along test runway centre line. Mast height 20 ft
Fig 4.4  Approach azimuth cross runway test GS60
Fig 4.5a

Fig 4.5b  Approach azimuth. Vehicle run along N–S runway. Mast height 20 ft.
Fig 4.6a Close and long range missed approach azimuth test points
Fig 4.6b Cross runway missed approach azimuth test points
Fig 4.7 Missed approach azimuth static test GS72, position B6
KINE BASE LINE EFFECT

Fig 4.8a Missed approach azimuth. Run along test runway centre line.
Mast at 20 ft
Fig 4.8b Missed approach azimuth. Run along test runway centre line. Mast at 20 ft.
Fig 4.8c Missed approach azimuth. Run along test runway centre line. Mast at 20 ft
Fig 4.10a  Missed approach azimuth. Vehicle run along cross road. Mast height 20 ft
Fig 4.10b  Missed approach azimuth. Vehicle run along cross road.
Mast height 30 ft
Fig 4.12

Elevation sub-system installation

Single storey buildings and permanent vehicles are shaded

Runway 27

Antenna boresight

Elevation subsystem

N

0 100 200

350

ATC vehicle

VHF ILS antenna

Feasibility phase

DMLS
Fig 4.13 Magnitude of ground reflection in front of elevation transmitter.
Range 1000 ft
Fig 4.14 Elevation static test GS52, position E3
Fig 4.15a  Elevation static test GS40, position E7
Fig 4.16a

Kineto base line in relation to approach azimuth flight paths.
Fig 4.16c  Kine base line in relation to elevation flight paths
Fig 4.17

Estimated ground reflected signal for azimuth ground plane antenna.

- Ground Reflection Loss (Typical)
- Attenuation Due to Antenna Vertical Pattern Shape
- Total Attenuation

To Direct Signal dB

Ground Reflected Signal Relative

Elevation Angle Deg

0 2 4 6 8 10 12 14 16

0 -10 -20
Fig 4.18  Predicted code angle difference between direct and ground reflected signal for 0.1 and 0.25 degree lateral slope during 2000 ft constant height radials.
Fig 4.20 Elevation angle and ground interference nulls for 2000 ft constant height radials
Fig 4.21a  Lateral ground slope in front of approach azimuth transmitter
Fig 4.21b  Lateral ground slope in front of missed approach azimuth transmitter.
True azimuth code angle = $\phi$

$\cos \phi = \frac{y}{R}$

Tilted array axis is $Y'Y'$

Array code angle = $\phi'$

$\cos \phi' = \frac{y'}{R} = \frac{1}{R} \left[ \frac{y}{\cos \beta} + (z - y \tan \beta) \sin \beta \right]$}

$$= \frac{1}{R} \left[ Z \sin \beta + y \left( \frac{1 - \sin^2 \beta}{\cos \beta} \right) \right]$$

$$= \frac{1}{R} \left( Z \sin \beta + y \cos \beta \right)$$

$$= \sin \theta \sin \beta + \cos \phi \cos \beta$$

Fig 4.22 Azimuth antenna tilt errors
OFFSET = -40.012 DEG
AA 32/3 30/9/76
H = 2250 FT
V = 123 KT

Fig 4.23a  Approach azimuth radial at -40 degrees
Fig 4.23c  Approach azimuth radial at -40 degrees

OFFSET = -40.012 DEG
AA 32/3  30/9/75
H = 2250 FT
V = 123 KT
OFFSET = -20.025 DEG
AA 37/6  6/11/75
H = 2890 FT
V = 143 KT

Fig 4.24b  Approach azimuth radial at -20 degrees
Fig 4.24c  Approach azimuth radial at -20 degrees
Fig 4.25c  Approach azimuth radial at 0 degree

M = 0.010°
2σT = 0.030°

OFFSET = 0.000 DEG
AB 14/7 5/6/75
H = 1520 FT
V = 204 KT

Fig 4.25c
Fig 4.26a  Approach azimuth radial at 0 degree
Fig 4.26c  Approach azimuth radial at 0 degree
Fig 4.27a  Approach azimuth radial at +20 degrees

AA 37/7  6/11/75
H = 2820 FT
V = 128 KT

OFFSET = 18.998 DEG

Fig 4.27a  Approach azimuth radial at +20 degrees
Fig 4.27c  Approach azimuth radial at +20 degrees
Fig 4.28b  Approach azimuth radial at +40 degrees
Fig 4.28c  Approach azimuth radial at +40 degrees
Fig 4.29a/b

Approach azimuth orbital flight

AW 10/1 3.875
H = 1930 FT R = 7.2 N. MILE
V = 67 KT ELEVATION ANGLE = 2.4°
Fig 4.29c  Approach azimuth orbital flight
Fig 4.30c  Approach azimuth orbital flight at 4100 ft. 5 n mile radius
Fig 4.32a  Approach azimuth accuracy.  3 degree approach to land and roll out.
Fig 4.32c  Approach azimuth accuracy.  3 degree approach to land and roll out
Fig 4.33a  Approach azimuth accuracy. 3 degree approach to touch and go
Fig 4.33c  Approach azimuth accuracy.  3 degree approach to touch and go
Fig 4.34a  Approach azimuth accuracy. 3 degree approach to low overfly
Fig 4.34c  Approach azimuth accuracy.  3 degree approach to low overfly.
Fig 4.35a  Missed approach azimuth radial flight on centre line
Fig 4.35c  Missed approach azimuth radial flight on centre line
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Fig 4.36c  Missed approach azimuth orbital flight at 1940 ft and 7.3 n mile radius
Fig 4.38c  Missed approach orbital flight at 2050 ft and 4.1 n mile radius
Fig 4.40a  3 degree approach using 60λ array missed approach guidance to low overshoot
Fig 4.40c 3 degree approach using 60λ array missed approach guidance to low overshoot
Fig 4.41a  Elevation accuracy. Radial flight at 2957 ft and 0 degree
Fig 4.42a  Elevation accuracy radial flight at 1900 ft and on -44 degrees radial
Fig 4.43a  Elevation accuracy radial flight at 1950 ft and on +51 degrees radial
Fig 4.44a Elevation orbital flight at 1980 ft and 6.5 n mile radius
Fig 4.44c  Elevation orbital flight at 1980 ft and 6.5 n mile radius
Fig 4.45a  Elevation orbital flight at 4100 ft and 4.1 n mile radius
Fig 4.4a/b  Elevation vertical ascent
Fig 4.46c  Elevation vertical ascent
Fig 4.47c  Elevation accuracy. 3 degree approach to touchdown
Fig. 4.48a  Elevation accuracy. 3 degree approach to 100 ft level overfly
Fig 4.48c  Elevation accuracy. 3 degree approach to 100 ft level overfly
Fig 4.49a  Elevation accuracy. 6 degree approach to 50 ft
Fig 4.49c  Elevation accuracy. 6 degree approach to 50 ft
Fig 4.51 Stability test – approach mean error
Fig 4.52  Stability test — approach azimuth daily mean error extremes
Fig 4.53 Stability test – approach azimuth daily standard deviation of means
Fig 4.54 Stability test — approach azimuth noise error rms
Fig 4.55  Stability test – missed approach azimuth mean error
Fig 4.56 Stability test — missed approach azimuth daily mean error extremes
Fig 4.57 Stability test – missed approach azimuth and standard deviation of means
Fig 4.58 Stability test — missed approach azimuth noise error rms
Fig 4.60 Stability test – elevation daily mean error extremes
Fig 4.61 Stability test – elevation daily standard deviation of means
Fig 4.62 Stability test — elevation noise error rms
Fig 5.1  TDM signal format
Fig 5.2 Relative frequencies of the angle and data components of the system.
Fig 5.3 Time frame arrangement (major alternatives)
(a) AZIMUTH SYSTEM - AZIMUTH COVERAGE PATTERN

(b) ELEVATION SYSTEM - ELEVATION COVERAGE PATTERN

Fig 5.4 OCI antenna patterns
Fig 5.5

**PREAMBLE**

**PULSE ANGLE SIGNALS**

1dB LIMIT FOR

**MUST BE OUT-OF-COVERAGE**

1dB LIMIT FOR

**MUST BE IN-COVERAGE**

**ELEVATION**

SEE

**FIGURE 2.2.8.2.**

**OCI PULSES RIGHT LEFT**

1dB LIMIT FOR

**MUST BE OUT-OF-COVERAGE TO-THE-LEFT**

**POINT A**

1dB LIMIT FOR

**MUST BE IN-COVERAGE TO-THE-RIGHT**

**POINT B**

OUT-OF-COVERAGE

**TO-THE-LEFT**

**POINT C**

**AZIMUTH**

Fig 5.5 OCI limits (as seen by the aircraft)
Fig 5.6 Typical ground facility
Fig. 5.7 Transmitter IF unit
Fig 5.8 Transmitter and antenna RF
Fig 5.9 Transmitter timing unit
Fig 5.11 Commutator switching
Fig 5.12

Azimuth vertical column element
Fig 5.14 Column element typical vertical radiation pattern
Fig 5.17 Elevation array element - azimuth radiation pattern
Fig 5.18  Elevation array element – elevation radiation pattern
Fig 5.19 Completed 54 wavelength GRP elevation array
Fig 5.20 Internal monitor – azimuth facility
Fig 5.22 - Field monitor

Primary Data from Remote Control (Azimuth Only)

Monitor Manifold

Commutated

Detector

Wideband Amplifier

Data Verification

D. P. S. K. Demodulator

Sync Pulse to Timing Generator

Prefix

Monitor Processor

Data

Alarms

Power

Power Detector

Angle Demodulator

Angle Comparator

Angle

Alarms
Fig 5.23a  Full capability receiver and control unit

Fig 5.23b  Internal view of receiver
Fig 5.24

Block diagram for TDM receivers

DATA

ANGLE OUTPUTS

DOPPLER DECODER

ANGLE SELECT

CONTROL UNIT

POWER SUPPLY

REFERENCE OSCILLATOR

SYNTHESISER

CHANNEL SELECT
Fig 5.25  Receiver RF/IF circuits
Fig 5.26 Data demodulator and decoder
Fig 5.27 RF/IF self test circuit
Fig 5.28 The Doppler signal

Doppler angle information

Time plane

One scan (Scan time T)

Doppler beat frequency $f_0$

Frequency plane

Single scan spectrum

Continuous

$\frac{\sin x}{x}$

Time

Frequency
Fig 5.29 Single frequency analogue correlator
Fig 5.30

Digital frequency correlator
Fig 5.31 Digital frequency generation
Fig 5.32 Correlator acquisition and validation process
Fig 5.33 The frequency spectrum resulting from the use of a sum taper function
Fig 5.34  The frequency spectrum resulting from the use of a taper function difference
Fig 5.35 Simple correlation system flow diagram